DOCUMENT RESUME

ED 090 391 CE 001 242

TITLE	Aviation Structural Mechanic S 3 & 2. NAVTRA-10308-C. Rate Training Manual.
INSTITUTION	Bureau of Naval Personnel, Washington, D.C.; Naval Training Publications Detachment, Washington, D.C.
REPORT NO	NAVTRA-10308-C
PUB DATE	74
NOTE	392p.
EDRS PRICE	MF-$0.75 HC-$18.60 PLUS POSTAGE
DESCRIPTORS	Armed Forces; *Aviation Mechanics; Aviation Technology; Equipment Maintenance; *Manuals; *Military Personnel; *Military Training; Repair; *Technical Education
IDENTIFIERS	Navy

ABSTRACT

This document is one of a series of rate training manuals designed to provide enlisted personnel of the Navy or Naval Reserve with the background information that will be useful in preparing for advancement in Aviation Structural Mechanics S (AMS) rating and to present necessary information for the proper performance of duties in that rating. The manual outlines the areas of Aviation Structural Mechanic S rating; aeronautic publications; aircraft materials; airframe construction; sheet-metal working machines, tools, and procedures; aircraft hardware; aircraft damage repair; airframe maintenance; landing wheels, tires and tubes; tubing, flexible hose, and clamps; corrosion control; and line operations and maintenance. Numerous illustrations, diagrams, photographs, and data tables are included. (KP)

ED 090391

U.S. DEPARTMENT OF HEALTH,
EDUCATION & WELFARE
NATIONAL INSTITUTE OF
EDUCATION
THIS DOCUMENT HAS BEEN REPRODUCED EXACTLY AS RECEIVED FROM THE PERSON OR ORGANIZATION ORIGINATING IT. POINTS OF VIEW OR OPINIONS STATED DO NOT NECESSARILY REPRESENT OFFICIAL NATIONAL INSTITUTE OF EDUCATION POSITION OR POLICY.

AVIATION
STRUCTURAL MECHANIC S 3 & 2

AE 001 242

NAVAL TRAINING COMMAND

RATE TRAINING MANUAL NAVTRA 10308-C

PREFACE

This Rate Training Manual is one of a series of training manuals prepared for enlisted personnel of the Navy and Naval Reserve who are studying for advancement in the Aviation Structural Mechanic S (AMS) rating. As indicated by the title, the manual is based on the professional qualifications for the rates AMS3 and AMS2, as set forth in the Manual of Qualifications for Advancement, NavPers 18068 (Series). A reading list, which includes USAFI texts recommended as study material for AMS personnel, is provided in the front of the manual.

Combined with the necessary practical experience, the completion of this manual will greatly assist the AMSAN and AMS3 in preparing for advancement. This training manual should also be valuable as a review source for the more senior rates.

This training manual was prepared by the Navy Training Publications Center, NAS Memphis, Millington, Tennessee, for the Chief of Naval Training. Technical review of the manuscript was provided by personnel of the AMS(A) School, NAS Memphis, Millington, Tennessee; the Naval Examining Center, Great Lakes, Illinois; and the Naval Aviation Integrated Logistic Support Center, Patuxent River, Maryland. Technical assistance was also provided by the Naval Air Systems Command.

THE UNITED STATES NAVY

GUARDIAN OF OUR COUNTRY

The United States Navy is responsible for maintaining control of the sea and is a ready force on watch at home and overseas, capable of strong action to preserve the peace or of instant offensive action to win in war.

It is upon the maintenance of this control that our country's glorious future depends; the United States Navy exists to make it so.

WE SERVE WITH HONOR

Tradition, valor, and victory are the Navy's heritage from the past. To these may be added dedication, discipline, and vigilance as the watchwords of the present and the future.

At home or on distant stations we serve with pride, confident in the respect of our country, our shipmates, and our families.

Our responsibilities sober us; our adversities strengthen us.

Service to God and Country is our special privilege. We serve with honor.

THE FUTURE OF THE NAVY

The Navy will always employ new weapons, new techniques, and greater power to protect and defend the United States on the sea, under the sea, and in the air.

Now and in the future, control of the sea gives the United States her greatest advantage for the maintenance of peace and for victory in war.

Mobility, surprise, dispersal, and offensive power are the keynotes of the new Navy. The roots of the Navy lie in a strong belief in the future, in continued dedication to our tasks, and in reflection on our heritage from the past.

Never have our opportunities and our responsibilities been greater.

CONTENTS

Chapter Page

1. Aviation Structural Mechanic S rating 1
2. Aeronautic publications 12
3. Aircraft materials 28
4. Airframe construction 57
5. Sheet-metal working machines, tools, and procedures 85
6. Aircraft hardware 119
7. Aircraft damage repair 155
8. Airframe maintenance 210
9. Landing wheels, tires, and tubes 235
10. Tubing, flexible hose, and clamps 258
11. Corrosion control 284
12. Line operations and maintenance 333

Index 381

READING LIST

USAFI TEXTS

United States Armed Forces Institute (USAFI) courses for additional reading and study are available through your Educational Services Officer.* The following courses are recommended:

C	151	General Mathematics I
C	152	General Mathematics II
D	700	General Aeronautics
E	275	General Science I
E	290	Physics I

* Members of the United States Armed Forces Reserve components, when on active duty, are eligible to enroll for USAFI courses, services, and materials if the orders calling them to active duty specify a period of 120 days or more, or if they have been on active duty for a period of 120 days or more.

CHAPTER 1

AVIATION STRUCTURAL MECHANIC S RATING

This training manual is designed as a self-study text for use by those personnel of the Navy and Naval Reserve who are preparing to meet the professional (technical) qualifications for advancement to petty officer third class and petty officer second class in the rating of Aviation Structural Mechanic S (Structures). Minimum professional qualifications for advancement are listed in the Manual of Qualifications for Advancement, NavPers 18068 (Series). In preparing for the advancement examination, this manual should be studied in conjunction with Military Requirements for Petty Officer 3 & 2, NavPers 10056 (Series). The latter covers the military requirements for all third and second class petty officers, as well as detailed information on the Naval Aviation Maintenance Program (NAMP).

The intent of this chapter is to provide information on the enlisted rating structure, the AMS rating, requirements and procedures for advancement, and references that will help you in performing your duties as an Aviation Structural Mechanic S. This chapter also includes information on how to make the best use of Rate Training Manuals. It is therefore strongly recommended that you study this chapter carefully before beginning intensive study of the remainder of the manual.

ENLISTED RATING STRUCTURE

The present enlisted rating structure consists of general ratings and service ratings.

General ratings identify broad occupational fields of related duties and functions. Some general ratings include service ratings; others do not. Both Regular Navy and Naval Reserve personnel may hold general ratings.

Service ratings identify subdivisions or specialties within a general rating which require related patterns of aptitudes and qualifications, and which provide paths of advancement for career development. The general rating provides the primary means of identifying billet requirements and personnel qualifications; it is established or disestablished by the Secretary of the Navy; and it is provided a distinctive rating badge. The term "rate" identifies personnel occupationally by pay grade. "Rating" refers to the occupational field. Service ratings can exist at any petty officer level, but they are most common at the PO3 and PO2 levels. Both Regular Navy and Naval Reserve personnel may hold service ratings.

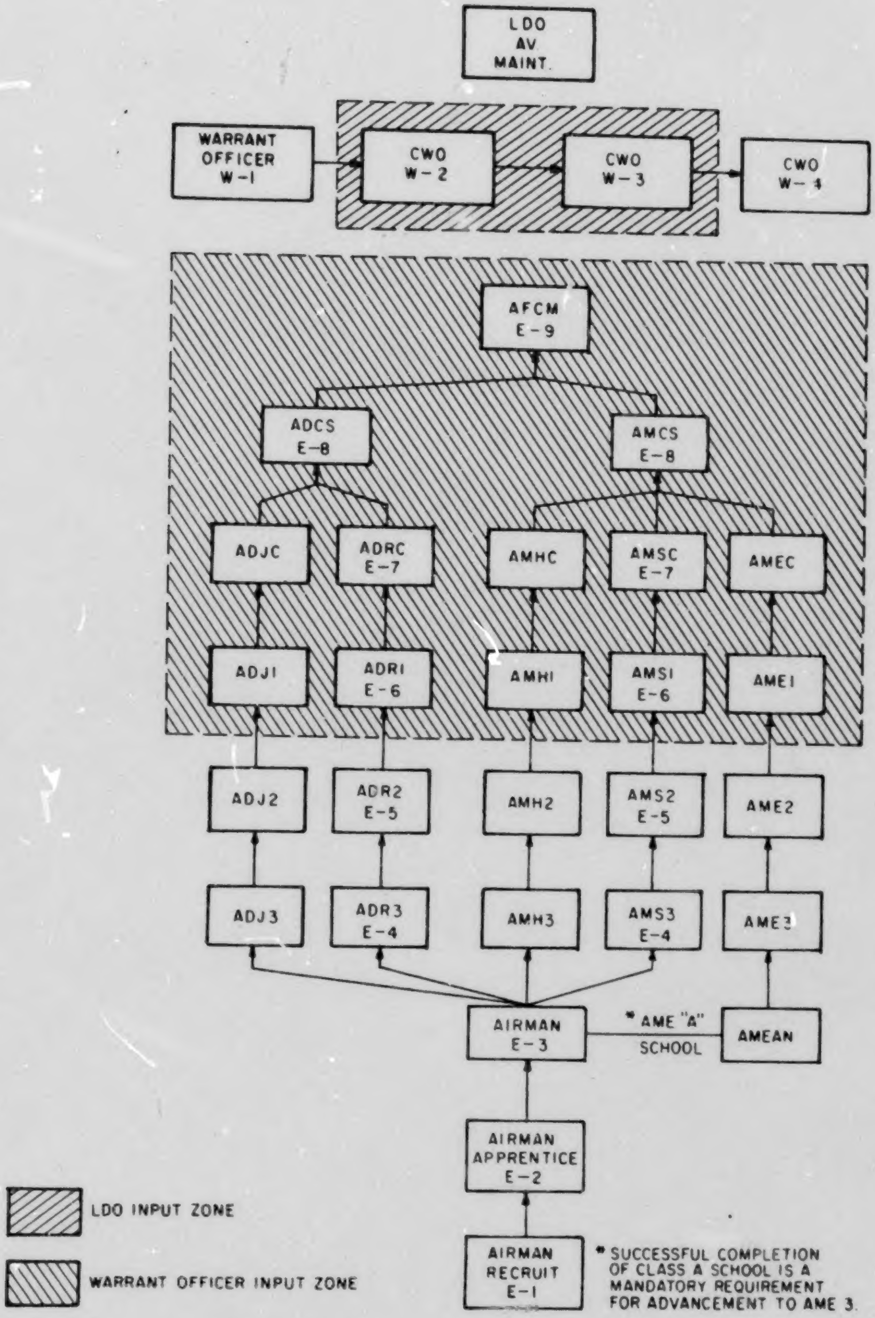
AVIATION STRUCTURAL MECHANIC (AM) RATING

The AM rating is divided into three service ratings at paygrades E-4 through E-7. The service ratings are AME (Safety Equipment), AMS (Structures), and AMH (Hydraulics).

At paygrade E-8 the general rating, AM, applies. Therefore, upon advancement to E-8, paygrade E-7 personnel (AMEC's, AMSC's and AMHC's) are combined to become Senior Aviation Structural Mechanics (AMCS').

At paygrade E-9 the AM rating loses its identity and personnel in the rating advance, along with ADCS', to Master Chief Aircraft Maintenancemen (AFCM's).

Figure 1-1 illustrates all paths of advancement for an Airman Recruit to Master Chief Aircraft



AM.1

Figure 1-1.—Paths of advancement.

Maintenanceman, Warrant Officer (W-4), or to Limited Duty Officer. Shaded areas indicate career stages where qualified personnel may advance to Warrant Officer (W-1) and selected Warrant Officers may advance to Limited Duty Officer. Personnel in enlisted rates and warrant ranks not in a shaded area may advance only as indicated by the lines.

The AMS maintains the fuselage, wings, stabilizers, movable surfaces, landing wheels and tires, and the flight control systems. In performing these duties the AMS fabricates and assembles various types of metallic and nonmetallic parts, makes minor skin repairs and structural repairs, replaces rivets and other types of metal fasteners, performs tire and wheel buildup, and paints aircraft. In performing these duties the AMS performs operational checks, locates troubles, removes and replaces malfunctioning components, and performs daily, preflight, postflight, and periodic inspections under the assigned AMS scope.

Duty assignments available to the AMS3 and AMS2 are limited only by the location of operating aircraft. Billets exist on most carriers from the smallest to the largest. AMS personnel assigned aboard carriers may be attached either to the ship or to one of the embarked squadrons. Regardless of how assigned, the AMS will be working with other maintenance personnel assisting in keeping the aircraft flying.

AMS personnel play an equally important role in patrol squadrons, which constitute a portion of the nation's antisubmarine warfare protection. By hard work and initiative, the AMS may become qualified as an aircrewman in patrol type aircraft.

Many interesting overseas shore billets exist for AMS's. If married, some third class and all second class petty officers may qualify to bring their dependents to these overseas locations at government expense. Shorter duty tours usually prevail at the few overseas stations where dependents are not allowed or choose not to go.

Between sea tours, the AMS Third of Second Class may be assigned to one of the many naval air stations along the Gulf, East Coast, and West Coast. In addition, the Naval Training Command has a few naval air stations located inland, from which aircraft are operated and AMS's may be assigned.

LEADERSHIP

One does not have to be a member of the Armed Forces very long before he realizes that more leadership is required of the higher rates. Advancement not only entails the acquisition of superior knowledge, but also the demonstrated ability to handle people. This ability increases in importance as one advances through the petty officer rates.

In General Order No. 21, the Secretary of the Navy outlined some of the most important aspects of naval leadership. By naval leadership is meant the art of accomplishing the Navy's mission through people. It is the sum of those qualities of intellect, of human understanding, and of moral character that enable a man to inspire and to manage a group of people successfully. Effective leadership therefore is based on personal example, good management practices, and moral responsibility. The term leadership includes all three of these elements.

The current Navy Leadership Program is designed to keep the spirit of General Order No. 21 ever before Navy personnel. If the threefold objective is carried out effectively in every command, the program will make better leaders of men in their present and future assignments. As one advances up the leadership ladder, more and more of his worth to the Navy will be judged on the basis of the amount of efficient work obtained from his subordinates rather than how much of the actual work is performed by himself.

For further information on the practical application of leadership and supervision, the latest edition of Military Requirements for Petty Officer 3 & 2, NavPers 10056-C, should be studied. The principles and problems of naval leadership covered in NavPers 15924 (Series) and the Leadership Checklist for Petty Officers, NavPers 2932-3, will be useful tools in developing sound leadership traits.

ADVANCEMENT

Some of the rewards of advancement are easy to see. You get more pay. Your job assignments become more interesting and more challenging. You are regarded with greater respect by officers and enlisted personnel. You enjoy the satisfaction of getting ahead in your chosen Navy career.

The advantages of advancement are not yours alone. The Navy also profits. Highly trained personnel are essential to the functioning of the Navy. By advancement, you increase your value to the Navy in two ways: First, you become more valuable as a technical specialist in your own rating; and second, you become more valuable as a person who can train others and thus make far-reaching contributions to the entire Navy.

HOW TO QUALIFY FOR ADVANCEMENT

What must you do to qualify for advancement? The requirements may change from time to time, but usually you must:

1. Have a certain amount of time in your present grade.
2. Complete the required Rate Training Manuals by either demonstrating a knowledge of the material in the manual by passing a locally prepared and administered test, or by passing the Enlisted Correspondence Course based on the Rate Training Manual and the appropriate military requirements manual.
3. Utilizing an appropriate Personnel Qualification Standard (when applicable) as a guideline, become qualified and demonstrate your ability to perform all the practical requirements for advancement by completing the Record of Practical Factors, NavPers 1414/1.
4. Be recommended by your commanding officer, after the petty officers and officers supervising your work have indicated that they consider you capable of performing the duties of the next higher rate.
5. Successfully complete the applicable military/leadership examination which is required prior to participating in the advancement (professional) examination.

Some of these general requirements may be modified in certain ways. One of these ways is through the accelerated advancement program (BuPers Note 1430 of 22 Sept. 1970). Figure 1-2 gives a more detailed view of the requirements for advancement of active duty personnel; figure 1-3 gives this information for inactive duty personnel.

Remember that the requirements for advancement can change. Check with your educational services office to be sure that you know the most recent requirements.

Advancement is not automatic. After you have met all the requirements, you are eligible for advancement. You will actually be advanced only if you meet all the requirements (including making a high enough score on the written examination) and if quotas permit.

HOW TO PREPARE FOR ADVANCEMENT

What must you do to prepare for advancement? You must study the qualifications for advancement, work on the personal qualification standard and practical factors, study the required Rate Training Manuals, and study other material that is required. You will need to be familiar with the following:

1. Manual of Qualifications for Advancement, NavPers 18068 (Series).
2. Personnel Qualification Standard for the equipment/system and rating assigned.
3. Record of Practical Factors, NavPers 1414/1.
4. Bibliography for Advancement Study, NavTra 10052 (Series).
5. Applicable Rate Training Manuals and their companion Enlisted Correspondence Courses.
6. Examinations for advancement.

Collectively, these documents make up an integrated training package tied together by the qualifications. The following paragraphs describe these materials and give some information on how each one is related to the others.

"Quals" Manual

The Manual of Qualifications for Advancement, NavPers 18068 (Series), gives the minimum requirements for advancement. This

REQUIREMENTS*	E1 to E2	E2 to E3	#† E3 to E4	#E4 to E5	† E5 to E6	† E6 to E7	† E7 to E8	† E8 to E9
SERVICE	4 mos. service– or completion of	6 mos. as E-2.	6 mos. as E-3	12 mos. as E-4	24 mos. as E-5.	36 mos. as E-6. 8 years total enlisted service.	36 mos as E-7. 8 of 11 years total service must be enlisted.	24 mos. as E-8. 10 of 13 years total service must be enlisted.
SCHOOL	Recruit Training (C.O. may advance up to 10% of graduating class.)		Class A for PR3, DT3, PT3, AME 3, HM 3, PN 3, FTB 3, MT 3.			Class B for AGC MUC, MNC ††		
PRACTICAL FACTORS	Locally prepared check-offs.	Record of Practical Factors, NavPers 1414/1, must be completed for E-3 and all PO advancements.						
PERFORMANCE TEST			Specified ratings must complete applicable performance tests before taking examinations.					
ENLISTED PERFORMANCE EVALUATION	As used by CO when approving advancement.		Counts toward performance factor credit in advancement multiple.					
EXAMINATIONS**	Locally prepared tests.	See below.	Navy-wide examinations required for all PO advancements.				Navy-wide, selection board.	
RATE TRAINING MANUAL (INCLUDING MILITARY REQUIREMENTS)		Required for E-3 and all PO advancements unless waived because of school completion, but need not be repeated if identical course has already been completed. See NavPers 10052 (current edition).					Correspondence courses and recommended reading. See NavPers 10052 (current edition).	
AUTHORIZATION	Commanding Officer		Naval Examining Center					

* All advancements require commanding officer's recommendation.

† 1 year obligated service required for E-5 and E-6; 2 years for E-7, E-8 and E-9.

# Military leadership exam required for E-4 and E-5.

** For E-2 to E-3, NAVEXAMCEN exams or locally prepared tests may be used.

†† Waived for qualified EOD personnel.

Figure 1-2.—Active duty advancement requirements.

REQUIREMENTS *	E1 to E2	E2 to E3	E3 to E4	E4 to E5	E5 to E6	E6 to E7	E8	E9
TOTAL TIME IN GRADE	4 mos.	6 mos.	6 mos.	12 mos.	24 mos.	36 mos. with total 8 yrs service	36 mos. with total 11 yrs service	24 mos. with total 13 yrs service
TOTAL TRAINING DUTY IN GRADE †	14 days	14 days	14 days	14 days	28 days	42 days	42 days	28 days
PERFORMANCE TESTS			Specified ratings must complete applicable performance tests before taking examination.					
DRILL PARTICIPATION	Satisfactory participation as a member of a drill unit in accordance with BUPERSINST 5400.42 series.							
PRACTICAL FACTORS (INCLUDING MILITARY REQUIREMENTS)	Record of Practical Factors, NavPers 1414/1, must be completed for all advancements.							
RATE TRAINING MANUAL (INCLUDING MILITARY REQUIREMENTS)	Completion of applicable course or courses must be entered in service record.							
EXAMINATION	Standard Exam		Standard Exam required for all PO Advancements. Also pass Military Leadership Exam for E-4 and E-5.				Standard Exam, Selection Board.	
AUTHORIZATION	Commanding Officer		Naval Examining Center					

* Recommendation by commanding officer required for all advancements.

† Active duty periods may be substituted for training duty.

Figure 1-3.—Inactive duty advancement requirements.

manual is usually called the "Quals" Manual, and the qualifications themselves are often called "quals". The qualifications are of two general types: military requirements, and professional (or technical) qualifications.

Military requirements apply to all ratings rather than to any one particular rating. Military requirements for advancement to third class and second class petty officer rates deal with military conduct, naval organization, military justice, security, watch standing, and other subjects which are required of petty officers in all other ratings.

Professional qualifications are technical or professional requirements that are directly related to the work of each rating.

Both the military requirements and the professional qualifications are divided into subject matter groups; then, within each subject matter group, they are divided into practical factors and knowledge factors. Practical factors are things you must be able to DO. Knowledge factors are things you must KNOW in order to perform the duties of your rate.

The qualifications for advancement and a bibliography of study materials are available in your educational services office. Study these qualifications and the military requirements carefully. The written examination for advancement will contain questions relating to the knowledge factors and the knowledge aspects of the practical factors of both the military requirements and the professional qualifications. If you are working for advancement to second class, remember that you may be examined on third class qualifications as well as on second class qualifications.

It is essential that the "quals" reflect current requirements of fleet and shore operations, and that new fleetwide technical, operational, and procedural developments be included. For these reasons, the qualifications are continually under evaluation. Although there is an established schedule for revisions to the "quals" for each rating, urgent changes to the "quals" may be made at any time. These revisions are issued in the form of changes to the "Quals" Manual. Therefore, never trust any set of "quals" until you have checked the change number against an up-to-date copy of the "Quals" Manual. Be sure you have the latest revision.

Personnel Qualification Standards

Personnel Qualification Standards (PQS) (OpNav Instruction 3500.34) are presently being utilized to provide guidelines in preparing for advancement and qualification to operate specific equipment and systems. They are designed to support the advancement requirements as stated in the "Quals" Manual.

The "Quals" and Record of Practical Factors are stated in broad terms. Each PQS is much more specific in its questions that lead to qualification. It provides an analysis of specific equipment and duties, assignments, or responsibilities which an individual or group of individuals (withinin the same rating) may be called upon to carry out. In other words, each PQS provides an analysis of the complete knowledge and skills required of that rating tied to a specific weapon system (aircraft and/or individual systems or components).

Each qualification standard has four main subdivisions in addition to an introduction and a glossary of PQS terms. They are as follows:

100 Series – Theory
200 Series – Systems
300 Series – Watchstations (duties, assignments, or responsibilities).
400 Series – Qualifications cards

The introduction explains the complete use of the qualification standard in terms of what it will mean to the user as well as how to use it.

The Theory (100 Series) section specifies the theory background required as a prerequisite to the commencement of study in the specific equipment or system for which the PQS was written. These fundamentals are normally taught in the formal schools (Preparatory, Fundamentals, and Class A) phase of an individual's training. However, if the individual has not been to school, the requirements are outlined and referenced to provide guidelines for a self-study program.

The Systems (200 Series) section breaks down the equipment or systems being studied into functional sections. PQS items are essentially questions asked in clear, concise statement (question) form and arranged in a standard format. The answers to the questions must be extracted from the various maintenance manuals covering the equipment or systems for which the PQS was written. This section asks the user to explain the function of the system, to draw a simplified version of the system from memory, and to use this drawn schematic or the schematic provided in the maintenance manual while studying the system or equipment. Emphasis is given to such areas as maintenance management procedures, components, component parts, principles of operation, system interrelations, numerical values considered necessary to operation and maintenance, and safety precautions.

The Watchstation (300 series) section includes questions regarding the procedures the individual must know to operate and maintain the equipment or system. A study of the items in the 200 series section provides the individual with the required information concerning what the system or equipment does, how it does it, and other pertinent aspects of operation. In the 300 series section, the questions advance the qualification process by requiring answers or demonstrations of ability to put this knowledge to use or to cope with maintenance of the system or equipment. Areas covered include normal operation; abnormal or emergency operation; emergency procedures which could limit damage and/or casualties associated with a particular operation; operations that occur too infrequently to be considered mandatory performance items; and maintenance procedures/instructions such as checks, tests, repair, replacement, etc.

The 400 series section consists of the qualification cards. These cards are the accounting documents utilized to record the individual's satisfactory completion of items necessary for becoming qualified in duties assigned. Where the individual starts in completing a standard will depend on his assignment within an activity. The complete PQS is given to the individual being qualified so that he can utilize it at every opportunity to become fully qualified in all areas of his rating and the equipment or system for which the PQS was written. Upon transfer to a different activity, each individual must requalify. The answers to the questions asked in the qualification standards may be given orally or in writing to the supervisor, the branch or division officer, and maintenance officer as required to certify proper qualification. The completion of part or all of the PQS provides a basis for the supervising petty officer and officer to certify completion of Practical Factors for Advancement.

Record of Practical Factors

Before you can take the Navy-wide examination for advancement, there must be an entry in your service record to show that you have qualified in the practical factors of both the military requirements and the professional qualifications. A special form known as the Record of Practical Factors, NavPers 1414/1 (plus the abbreviation of the appropraite rating), is used to keep a record of your practical factor qualifications. The form lists all practical factors, both military and professional. As you demonstrate your ability to perform each practical factor, appropriate entries are made in the DATE and INITIALS columns.

Changes are made periodically to the Manual of Qualifications for Advancement and revised forms of NavPers 1414/1 are provided when necessary. Extra space is allowed on the Record of Practical Factors for entering additional practical factors as they are published in changes. The Record of Practical factors also provides space for recording demonstrated proficiency in skills which are within the general scope of the rate but which are not identified as minimum qualifications for advancement.

If you are transferred before you qualify in all practical factors, NavPers 1414/1 should be forwarded with your service record to your next duty station. You can save yourself a lot of trouble by making sure that this form is actually inserted in your service record before you are transferred. If the form is not in your service record, you will be required to start all over again and requalify in the practical factors which have already been checked off.

A second copy of the Record of Practical Factors should be made available to each man in pay grades E-2 through E-8 for his personal record and guidance.

The importance of NavPers 1414/1 cannot be overemphasized. It serves as a record to indicate to the petty officers and officers supervising your work that you have demonstrated proficiency in the performance of the indicated practical factors and is part of the criteria utilized by your commanding officer when he considers recommending you for advancement. In addition, the proficient demonstration of the applicable practical factors listed on this form can aid you in preparing for the examination for advancement. Remember that the knowledge aspects of the practical factors are covered in the examinations for advancement. Certain knowledge is required to demonstrate these practical factors and additional knowledge can be acquired during the demonstration. Knowledge factors pertain to that knowledge which is required to perform a certain job. In other words, the knowledge factors required for a certain rating depend upon the jobs (practical factors) that must be performed by personnel of that rating. Therefore, the knowledge required to proficiently demonstrate these practical factors will definitely aid you in preparing for the examination for advancement.

NavTra 10052

Bibliography for Advancement Study, NavTra 10052 (Series), is a very important publication for anyone preparing for advancement. This bibliography lists required and recommended Rate Training Manuals and other reference material to be used by personnel working for advancement. NavTra 10052 is revised and issued once each year by the Naval Training Command. Each revised edition is identified by a letter following the NavTra number. When using this publication, be sure that you have the most recent edition.

If extensive changes in qualifications occur between the annual revisions of NavTra 10052, a supplementary list of study material may be issued in the form of a Notice. When you are preparing for advancement, check to see whether changes have been made in the qualifications. If changes have been made, see if a BuPers Notice has been issued to supplement NavTra 10052.

The required and recommended references are listed by rate level in NavTra 10052. If you are working for advancement to third class, study the material that is listed for third class. If you are working for advancement to second class, study the material that is listed for second class. Remember that you are also responsible for the references listed at the third class level.

In using NavTra 10052, you will notice that some Rate Training Manuals are marked with an asterisk (*). Any manual marked in this way is MANDATORY–that is, it must be completed at the indicated rate level before you are eligible to take the Navy-wide examination for advancement. Each mandatory manual may be completed by passing the appropriate enlisted correspondence course that is based on the mandatory training manual; passing locally prepared tests based on the information given in the training manual, or in some cases, successfully completing an appropriate Class A School.

Do not overlook the section of NavTra 10052 which lists the required and recommended references relating to the military standards/requirements for advancement. For example, all personnel must complete the Rate Training Manual, Military Requirements for Petty Officer 3 & 2, NavPers 10056 (Series), for the appropriate rate level before they can be eligible to advance.

The references in NavTra 10052 which are recommended, but not mandatory, should also be studied carefully. All references listed in NavTra 10052 may be used as source material for the written examinations at the appropriate rate levels.

Rate Training Manuals

There are two general types of Rate Training Manuals. Rating manuals (such as this one) are prepared for most enlisted rates, giving information that is directly related to the professional qualifications. Basic manuals give information that applies to more than one rate and rating. Basic Electricity, NavPers 10086 (Series), is an example of a basic manual, because many ratings use it for reference.

Rate Training Manuals are produced by field activities under the management control of the Naval Training Command. Manuals are revised from time to time to keep them up to date technically. The numbering system is being changed from NavPers to NavTra. The revision of a Rate Training Manual is identified by a letter following the NavPers or NavTra number. You can tell whether any particular copy of a Rate Training Manual is the latest edition by checking the number in the most recent edition of List of Training Manuals and Correspondence Courses, NavTra 10061 (Series). NavTra 10061 is actually a catalog that lists training manuals and correspondence courses; you will find this catalog useful in planning your study program.

Rate Training Manuals are designed to help you prepare for advancement. The following suggestions may help you to make the best use of this manual and other Navy training publications when you are preparing for advancement.

1. Study the military requirements and the professional qualifications for your rate before you study the training manual, and refer to the "quals" frequently as you study. Remember, you are studying the training manual in order to meet these "quals."

2. Set up a regular study plan. If possible, schedule your studying for a time of day when you will not have too many interruptions or distractions.

3. Before you begin to study any part of the training manual intensively, become familiar with the entire manual. Read the preface and the table of contents. Check through the index. Look at the appendixes. Thumb through the manual without any particular plan, looking at the illustrations and reading bits here and there as you see things that interest you.

4. Look at the training manual in more detail, to see how it is organized. Look at the table of contents again. Then, chapter by chapter, read the introduction, the headings, and the subheadings. This will give you a clear picture of the scope and content of the manual. As you look through the manual in this way, ask yourself some questions: What do I need to learn about this? What do I already know about this? How is this information related to information given in other chapters? How is this information related to the qualifications for advancement?

5. When you have a general idea of what is in the training manual and how it is organized, fill in the details by intensive study. In each study period, try to cover a complete unit—it may be a chapter, a section of a chapter, or a subsection. If you know the subject well, or if the material is easy, you can cover quite a lot at one time. Difficult or unfamiliar material will require more study time.

6. In studying any one unit—chapter, section, or subsection—write down the questions that occur to you. Many people find it helpful to make a written outline of the unit as they study, or at least to write down the most important ideas.

7. As you study, relate the information in the training manual to the knowledge you already have. When you read about a process, a skill, or a situation, try to see how this information ties in with your own past experience.

8. When you have finished studying a unit, take time out to see what you have learned. Look back over your notes and questions. Maybe some of your questions have been answered, but perhaps you still have some that are not answered. Without referring to the training manual, write down the main ideas that you have learned from studying this unit. Do not quote the manual. If you cannot give these ideas in your own words, the chances are that you have not really mastered the information.

9. Use Enlisted Correspondence Courses whenever you can. The correspondence courses are based on Rate Training Manuals or on other appropriate texts. As mentioned before, completion of a mandatory Rate Training Manual can be accomplished by passing an Enlisted Correspondence Course based on the Rate Training Manual. You will probably find it helpful to take other correspondence courses, as well as those based on mandatory training manuals. Taking a correspondence course helps you to master the information given in the training manual, and also helps you see how much you have learned.

10. Think of your future as you study Rate Training Manuals. You are working for advancement to third class or second class right now, but someday you will be working toward higher rates. Anything extra that you can learn now will help you.

SOURCES OF INFORMATION

One of the most useful things you can learn about a subject is how to find out more about it. No single publication can give you all the information you need to perform the duties of your rating. You should learn where to look for accurate, authoritative, up-to-date information on all subjects related to the military requirements for advancement and the professional qualifications of your rating.

Some of the publications described in this chapter are subject to change or revision from time to time–some at regular intervals, others as the need arises. When using any publication that is subject to change or revision, be sure that you have the latest edition. When using any publication that is kept current by means of changes, be sure you have a copy in which all official changes have been made. Studying canceled or obsolete information will not help you to do your work or to advance in rating; it is likely to be a waste of time, and may even be seriously misleading.

Several publications that you will need to study or refer to as you prepare for advancement have already been discussed earlier in this chapter. In addition, you may find it useful to consult some of the Rate Training Manuals prepared for other Group IX (Aviation) ratings. Reference to these training manuals will add to your knowledge of the duties of other men in the field of aviation. Also, you may find it useful to consult the Basic Rate Training Manuals described in the following paragraphs.

Tools and Their Uses, NavPers 10085 (Series), contains descriptions of a number of basic handtool operations that are performed by enlisted men of all ratings in their day-to-day work. The manual is plentifully supplied with illustrations showing, as well as telling, how to perform specific operations. Many of the jobs performed by the AMS are included, making it a valuable reference not only in performing your daily duties but also in studying for advancement.

It is essential that AMS's have a thorough understanding of basic machines. Basic Machines, NavPers 10624, contains an excellent presentation on basic machines. Beginning with the simplest of machines–the lever–the manual proceeds with the discussion of block and tackle, wheel and axle, inclined plane, screw, and gears. It explains the concepts of work and power, and differentiates between the terms "force" and "pressure." The fundamentals of hydrostatic and hydraulic mechanisms are discussed in detail. The final chapter includes several examples of the combination of simple mechanisms to make complex machines.

A thorough understanding of the material presented in Basic Machines will greatly facilitate an understanding of the machines with which the AMS works, many of which are a combination of a number of simple machines.

Additional publications that you may find useful are as follows:

Blueprint Reading and Sketching, NavPers 10077 (Series).

Basic Electricity, NavPers 10086 (Series) (chapters 1, 3).

Fluid Power, NavPers 16193 (Series).

CHAPTER 2

AERONAUTIC PUBLICATIONS

Aeronautic publications are issued by authority of the Commander of the Naval Air Systems Command. These publications are the sources of information for guiding naval personnel in the operation and maintenance of all aircraft and related equipment within the Naval Establishment. By proper use of these publications, all aircraft and other aeronautic equipment can be operated and maintained efficiently and uniformly throughout the Navy.

Aeronautic publications may be grouped into two major classes or groups—those issued in the form of MANUALS, and those issued in the form of LETTER MATERIAL.

When a new aircraft, engine, accessory, or other item of equipment is accepted by the Navy, manuals necessary to insure its proper operation and upkeep are prepared and issued to all activities using and/or maintaining the equipment. Supplemental information and other directive type publications that must be issued from time to time are issued in the form of letter material. Both manual and letter publications may, on occasion, be properly referred to as directives. Broadly speaking, any communication which initiates or governs action, conduct, or procedure is a directive.

All aeronautic publications, both manual and letter type, are assigned a title and code number. When they are available for issue, all publications, except Instructions and Notices, are listed in the Naval Aeronautic Publications Index.

NAVAL AERONAUTIC PUBLICATIONS INDEX

The Naval Aeronautic Publications Index is made up of six parts, each of which serves a specific purpose. They are identified as follows:

Airborne Weapons/Stores, Conventional/Nuclear, Checklists/Stores Reliability Cards/Manual, NavAir 01-700. This part of the publications index is not used by AMS personnel and therefore is given no further coverage in this chapter.

Navy Stock List of Forms and Publications, NavSup Publication 2002; Section VIII, Parts C and D, Numerical Sequence List (also referred to as Numerical Index).

Equipment Applicability List (Volumes 1 through 7), NavAir 00-500A.

Aircraft Application List, NavAir 00-500B.

Directives Application List, NavAir 00-500C.

Letter Type Technical Directives Equipment and Subject Application List, NavAir 00-500D.

A description of these lists and their uses is presented in the following paragraphs.

NUMERICAL SEQUENCE LIST

NavSup Publication 2002 is a 13-section index of all the forms and publications used throughout the Navy and stocked by the Naval Supply Systems Command. Section VIII of this Stock List contains Naval Air Systems Command (NavAirSysCom) publications. This section is made up of four parts—A, B, C, and D.

Parts A and B pertain to ordnance publications. Part C is the numerical listing of manual type aeronautic technical publications, and Part D is the numerical listing of letter type publications. These two, Parts C and D, are referred to as the Numerical Sequence List or Numerical Index of the Naval Aeronautic Publications Index.

Part C (manual publications) contains its table of contents, as well as the instructions for using both Parts C and D of NavSup Publication 2002. Included in these instructions are the method for procuring aeronautic publications, the forms and procedures required for ordering publications, and explanations of certain codes used in the Index. Also a listing of canceled publications for Part C is contained in the last pages of Part C.

Part C is divided into subject matter groups, and all publications within a group are then listed in numerical order. For example, all manuals in the 00 series are listed first, then followed by the 01, 02, 03, etc., through the 51 series. The listing includes the publication code number, stock number, title, date of latest issue or revision, security classification, requisition restriction code, and basic or change code. A listing of the general subject groups is shown in table 2-1.

Part D (letter type directives) contains a table of contents, a general alphabetical cross-reference listing, and a listing of Air Force-Navy code cross-references.

Part D is divided into a number of subsections. Included among those of interest to the AMS are general, aircraft, accessories, and support equipment. Listed in the general section are Aircrew System Bulletins and Changes, Aviation Clothing and Survival Equipment Bulletins and Changes, Technical Orders, and Technical Notes. In the aircraft section are listed all Aircraft Changes and Bulletins. The accessories section contains a listing of all Accessories Changes and Bulletins. The support equipment section contains a listing of all Support Equipment Changes and Bulletins.

The Numerical Index must be used to completely identify and, therefore, to order required publications. However, the other parts of the Index (discussed in the following paragraphs) must be used to determine what publications are available for a specific item of equipment and to check the applicability of publications to specific equipment.

When an applicable publication number is found in one of the other parts of the Naval Aeronautic Publications Index, it can be easily located in the Numerical Index. Here, it can be more completely identified as to title and nomenclature, stock number (for manual type publications), security classification, and any restrictions concerning the requisitioning of the publication. In addition, the date of the latest issue or revision of the publication is listed. This provides a means whereby the issue and/or revision dates of the publications on hand in an activity can be checked against the dates listed in the current issue and supplement (discussed later) of the Numerical Index, thus assuring that the publications are current.

EQUIPMENT APPLICABILITY LIST

Basically, the Equipment Applicability List, NavAir 00-500A, is a cross-reference index listing of Naval Air Systems Command (NavAirSysCom) publications of aircraft components

Table 2-1.–General subject classification numbers for manual type publications.

General	00
Aircraft	01
Powerplants (02A Reciprocating engines, 02B Jet engines, 02F Rocket engines)	02
Accessories	03
Hardware and Rubber Material	04
Instruments	05
Fuels, Lubricants, and Gases	06
Dopes and Paints	07
Electronics	08 & 16
Instructional Equipment and Training Aids	09 & 28
Photography	10
Aviation Armament	11
Fuel and Oil Handling Equipment	12
Parachute and Personal Survival Equipment	13
Hangars and Flying Field Equipment	14
Standard Preservation and Packaging Instructions	15
Machinery, Tools, and Test Equipment	17 & 18
Ground Servicing and Automotive Equipment	19
Descriptive Data Sheets for Aviation Support Equipment (Being superseded by Ground Support Equipment Illustrations (GSEI))	20
Chemical Equipment	24 & 39
Meteorology	50
Ship Installations	51

and related equipment according to model, type, or part number.

Since this index contains several thousand entries, one volume would be very cumbersome to use. For this reason, this index is divided into several volumes. At the time of this writing, there are seven volumes.

With the exception of several small sections in the first part of Volume 1, the Equipment Applicability List is one continuous index of model, type, or part numbers in alphanumerical sequence.

In addition to an Introduction, which explains the headings at the top of each page, the other sections in the first part of Volume 1 pertain primarily to manuals for aircraft, weapons systems, and aircraft engines. Therefore, the publication numbers are listed according to aircraft, aircraft engine, and weapons system designation.

The Equipment Applicability List should be used when attempting to determine what publications are available on a particular item of equipment, and the manufacturer and part number of the item are known.

AIRCRAFT APPLICATION LIST

The Aircraft Application List, NavAir 00-500B, contains a listing of all manuals grouped according to their application to an aircraft. This part of the index does not contain listings of any letter type publications, and all manuals are listed by publication code number only.

A list of basic numbering categories is provided in the front of the book. This list may be used in determining the general type of equipment covered in a publication. For determining the specific item of equipment covered by a publication and the title of the publication, reference should be made to Part C of Section VIII in NavSup Publication 2002.

The Aircraft Application List is especially handy for determining what manuals are available for a particular model of aircraft. Included under each model is a complete listing of applicable manuals. This listing includes all allowance lists, aircraft manuals, engine manuals, accessories manuals, etc., pertaining to that particular model of aircraft.

DIRECTIVES APPLICATION LIST BY AIRCRAFT CONFIGURATION

The Directives Application List by Aircraft Configuration, NavAir 00-500C, contains a listing of the active Naval Air Systems Command letter type technical directives with respect to their applicability to aircraft. The lists in this volume are arranged first by aircraft series, second by aircraft configuration, and third by Airframe/Aircraft Bulletin and/or Change numbers. NOTE: Configuration refers to modifications made to a basic aircraft model. For instance, A-4A, A-4B, TA-4F, etc., are all different configurations of the A-4 aircraft model.

EQUIPMENT AND SUBJECT APPLICABILITY LIST

The Equipment and Subject Applicability List, NavAir 00-500D, is a relatively recent addition to the Naval Aeronautic Publications Index. It contains a cross-reference index listing of Naval Air Systems Command letter type technical directives. It serves the same purpose for letter type technical directives as the Equipment Applicability List, NavAir 00-500A, does for technical manuals. However, since the NavAir 00-500D lists only those model/type part numbers for which technical directives have been issued, it is much smaller than the NavAir 00-500A. The complete List is contained in one volume but is divided into two parts. Part A is the Equipment Index and Part B is the Subject Index.

Part A contains a listing of all Naval Air Systems Command letter type technical directives on aircraft components and related equipment by model/type part number. Each number is listed in alphanumerical sequence within its cognizant equipment series. At the present time, Part A is divided into nine series. The Accessories, Aircrew Systems, and Clothing and Survival Equipment Series are of most interest to AM personnel.

Part B of NavAir 00-500D contains a listing of active Naval Air Systems Command letter type directives by subject. This part of the List pertains primarily to Airframe Bulletins and Changes.

UPDATING THE INDEX

Each List in the Naval Aeronautic Publications Index is updated at regular intervals by the issuance of a new list. In addition, some of these Lists are kept current by the periodic issuance of supplements between issues of the Basic List. The dates and intervals of the issuance of new Lists and supplements have changed from time to time in the past.

At the time of this writing, the Numerical Index (Parts C and D of NavSup Publication 2002) is issued annually in September. Supplements are issued bimonthly between each basic issue. The Equipment Applicability List, NavAir 00-500A, is issued annually in November. This List is kept current by the issuance of quarterly supplements between each basic issue. The Aircraft Application List, NavAir 00-500B, is issued in March and September, and the Directives Application List by Aircraft Configuration, NavAir 00-500C, is issued in January and July of each year. Supplements are not issued for these Lists.

The Equipment and Subject Application List, NavAir 00-500D, is issued in May and November of each year, and as of this writing, supplements will be issued as the information is developed.

Supplements list all aeronautic publications distributed during the previous period, and those publications that have been superseded, canceled, or revised. Supplements are cumulative, that is, all material from the preceding supplement is incorporated in the latest supplement; therefore, at any given time, not more than one supplement is in effect for any List. Naturally, the reissue of a basic List cancels the outstanding supplement.

Supplements for the Numerical Index (Parts C and D of Section VIII of NavSup Publications 2002) are identified by the word "supplement" printed near the upper right-hand corner of the cover. Supplements to the NavAir 00-500A Series publications are identified by the word "supplement" printed in the middle of the cover page.

PUBLICATIONS NUMBERING SYSTEM

Code numbers are assigned to all publications in order that they may be identified, indexed, and filed. A knowledge of the numbering systems used will enable the AMS to locate any desired information with a minimum of effort. A brief explanation of the coding of manuals listed in the index is given in the following sections. Coding for letter type material is covered later in this chapter.

Code numbers assigned to manuals consist of a prefix and a series of three parts. The prefix consists of letters which identify the originator of the publication.

NavAir is the prefix assigned to technical publications originated by the Naval Air Systems Command. In the stock list, it is shortened to NA.

The three parts which make up the remaining portions of the number indicate the following:

Part I is a two-digit number that indicates the general subject classification of the equipment covered by the publication. Table 2-1 lists the general subject categories and the appropriate two-digit numbers.

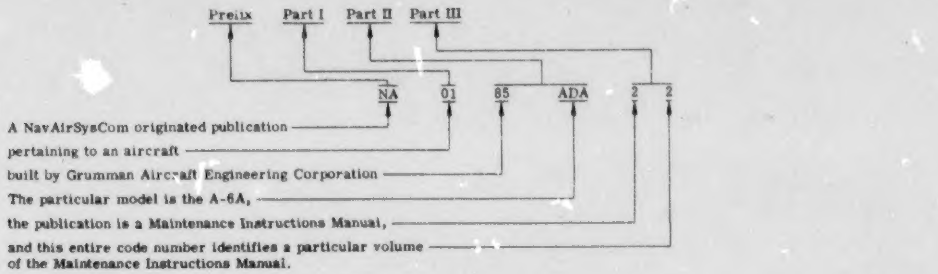
Part II of the publications code number consists of numbers and/or numbers and letters and indicates the specific class, group, type, or model and manufacturer of the equipment. The subject breakdowns are listed at the beginning of each separate major division within the Numerical Index.

Part III consists of a number or numbers which designate a specific manual. For aircraft and powerplants, this number designates a specific type of manual. For other types of equipment, this part is assigned in numerical sequence and has no reference to the type of manual.

Figure 2-1 illustrates the identification and decoding of a complete manual publication number.

SECURITY OF CLASSIFIED PUBLICATIONS

The Department of the Navy Supplement to the DOD Information Security Program Regulations (OpNav Instruction 5510.1 Series), issued by the Chief of Naval Operations, is the basic security directive relating to safeguarding classified information. Its provisions apply to all


Prefix
Part I
Part II
Part III
NA
01
85
ADA
2
2
A NavAirSysCom originated publication
pertaining to an aircraft
built by Grumman Aircraft Engineering Corporation
The particular model is the A-6A,
the publication is a Maintenance Instructions Manual,
and this entire code number identifies a particular volume of the Maintenance Instructions Manual.

AM.224

Figure 2-1.—Identification and decoding of manual publication code number.

military and civilian personnel and to all activities of the Naval Establishment.

The manual contains detailed instructions for classifying, marking, and handling classified information, and for access to and authorized disclosure of the information.

The AMS, from time to time, has occasion to use classified publications relating to the performance of his work. Before he accepts such publications he must be cleared to the appropriate degree to handle this classified matter. It is then mandatory that he have knowledge of and abide by the instructions in the Security Manual pertaining to handling classified material.

Publications listed in the Numerical Index (Parts C and D of Section VIII of NavSup Publication 2002) are unclassified unless otherwise marked "1" (confidential) or "4" (secret) in the column headed PS (physical security). The Index is not classification authority. The supplements to the Index contain information of classification action on a "when-occurring" basis.

MANUAL TYPE PUBLICATIONS

To attain a satisfactory state of readiness, technical manuals are developed, published, and distributed concurrently with the weapon system or equipment that they cover. Periodic changes and revisions are issued as necessary to insure that manuals continually reflect equipment changes and current operational and support concepts and procedures.

The Rapid Action Change (RAC) System provides a quick response capability for the delivery of urgently required technical information. Under this system, information affecting flight safety, hazards to personnel, or grounding of aircraft is disseminated via naval message and immediately incorporated into the affected manual. A manual change page followup is then required within 15 days of the release of the message. Information of a less urgent nature is disseminated by RAC change pages that must be printed within 30 days after problem resolution and is generally limited to 12 pages or less.

The RAC System for manual changes replaces the previous Interim Manual Change System but does not affect the normal manual change and revision requirements. It merely supplements the existing Normal Change System to provide for rapid issue of urgently required data which previously was not available to the user for long periods of time due to system red tape, such as routing and printing delays.

As shown in table 2-1, manuals are published in a number of different general subject categories. Those of special interest to the AMS3 and AMS2 are the General Manuals (00 series), Aircraft Manuals (01 series), and the Accessories Manuals (03 series). Certain manuals in other series may be used occasionally, but those listed here are of special importance to the Aviation Structural Mechanic.

GENERAL MANUALS (00 SERIES)

As indicated by the title, this series of manuals includes information of interest to all naval aviation personnel. Included are four parts of the Naval Aeronautic Publications Index (00-500A, 00-500B, 00-500C, and 00-500D, already described), NavAir Outfitting Lists and

Allowance Lists, and Aviation Training Literature.

Allowance Lists and Outfitting Lists (00-35Q Series)

Allowance Lists and Outfitting Lists consist of listings of the equipment and material necessary to place and maintain various activities in a material readiness condition. These allowances are based on known or estimated requirements or on available usage data.

Allowance Lists are identified by SECTIONS. Certain sections such as A, H, and K are issued as individual publications. Others such as B and R appear as a series of publications, each of which is applicable to a specific model of equipment, model of aircraft, or type of activity.

The AMS should be familiar with the following sections:

Section A, Standard Aeronautical and Navy Stock Account Material.

Section B, Airframe and Engine Maintenance Parts. This section contains the initial outfitting list for each model of aircraft in current use.

Section G, General Support Equipment. This section lists all consumable general support equipment for all classes, types, and models of aircraft.

Section H, Flight Operational Material for Aircraft Squadrons. This section lists aviator's flight clothing as well as the protective clothing available for use when handling liquid oxygen.

Section K, Allowance List for Naval Aeronautic Publications and Forms.

Allowance Lists are reissued periodically. When new issues or reissues are published, they are listed in the next issue of the Numerical Index. All lists not appearing in the current issue of the Numerical Index or latest supplement have been canceled.

All Allowance List and Outfitting List code numbers are NA 00-35Q plus the section identification letter and a dash number to identify a particular section in a series. For example, the Section B Allowance List for the S-2D aircraft is NA 00-35QB-177. This publication contains the initial outfitting list for the S-2D aircraft.

Training Literature (00-80 Series)

This series of publications is issued by authority of the Deputy Chief of Naval Operations (Air). Included are various Air Safety Pamphlets and General Aviation Training Publications. All such publications listed in the current issue of the Numerical Index are available at the various NavAir Publications Supply Points. All requests for 50 or more copies of a publication must be submitted to the Chief of Naval Operations, Flight Training Branch, Washington, D. C., with a statement of justification.

AIRCRAFT MANUALS (01 SERIES)

The following types of manuals are prepared and issued for each model of aircraft used by the Navy:

NATOPS Flight Manual.

Maintenance Instructions Manual.

Structural Repair Manual.

Periodic Maintenance Requirements Manual or Periodic Maintenance Information Cards.

Illustrated Parts Breakdown.

Technical Manual of Weight and Balance Data (certain aircraft only).

NATOPS Flight Manual

The NATOPS (Naval Air Training and Operating Procedures) Flight Manual contains complete operating instructions for the aircraft and its operational equipment. Emergency operating instructions as well as normal operating instructions are provided. Although NATOPS Flight Manuals are issued primarily for the use of pilots and aircrewmen, all maintenance personnel should become familiar with the contents of the Flight Manual for their respective aircraft.

NATOPS Flight Manuals are kept up to date by two types of revisions–regular revisions and interim revisions. Regular revisions cover routine changes and instructions and are generally issued every 90 days. Interim revisions cover vital operating instructions and are used when immediate action is necessary. Interim revisions may be issued in letter form to the individual activities and by naval message to commands, and are later incorporated as regular revisions.

Maintenance Instructions Manuals

The Maintenance Instructions Manuals (MIM's) contain all the essential information required by aircraft maintenance personnel for service and maintenance of the complete aircraft. MIM's include the data necessary for troubleshooting and maintaining the powerplant, accessories, and all other systems and components of the aircraft.

Maintenance Instructions Manuals are divided into three types. Type I manuals contain all essential information required for performing Organizational level maintenance, such as description and operation of systems and components, maintenance considerations, and appropriate diagrams and schematics.

Type II manuals contain Intermediate level maintenance instructions required for the maintenance of components, systems, groups of systems, or equipment when separate coverage is not provided in other manuals. Included are procedures for checkout, troubleshooting, repair, replacement, adjustment, calibration, and preinstallation, and/or shipping information (method of packaging). Coverage on components or equipment may include a description of component operation if it is not covered in the Type I manual.

Type III manuals contain Depot level overhaul and repair instructions for components, accessories, and any other equipment necessary for unit operation.

In many cases, a consolidation of any combination of Types I, II, or III manuals is provided in one manual. This is the type discussed in the following paragraphs and most common to the AMS.

The Maintenance Instructions Manual for all current production aircraft is made up in volumes, each volume being individually bound and issued separately. This permits each shop in an activity to have its own applicable volume, or volumes, at hand for ready reference. Volumes of most interest to the AMS are as follows:

General Information and Servicing.
Landing Gear and Arresting Gear Systems.
Airframe and Related Systems.
Flight Control Systems.
Corrosion Control - Cleaning, Painting, and Decontamination.

NOTE: The different aircraft manufacturers may group the material in the various volumes of the Maintenance Instructions Manuals under different titles. For example, the Survival and Environmental Systems volume for the RA-5C covers the ejection seat, canopy, liquid oxygen, heating, air-conditioning, ventilation, and anti-g systems. Two volumes, titled Personnel Environmental Systems and Canopy and Survival Systems, are prepared to cover the same subjects for the A-4 aircraft.

The General Information and Servicing volume is designed primarily for the plane captain; however, this volume also contains a great deal of information important to all AMS personnel. This volume contains a general description of the aircraft, all necessary information which is not contained in other specialized manuals, and all information pertaining to servicing the aircraft.

Each of the specialized system volumes of the Maintenance Instructions Manual is further divided into four sections, as described in the following paragraphs.

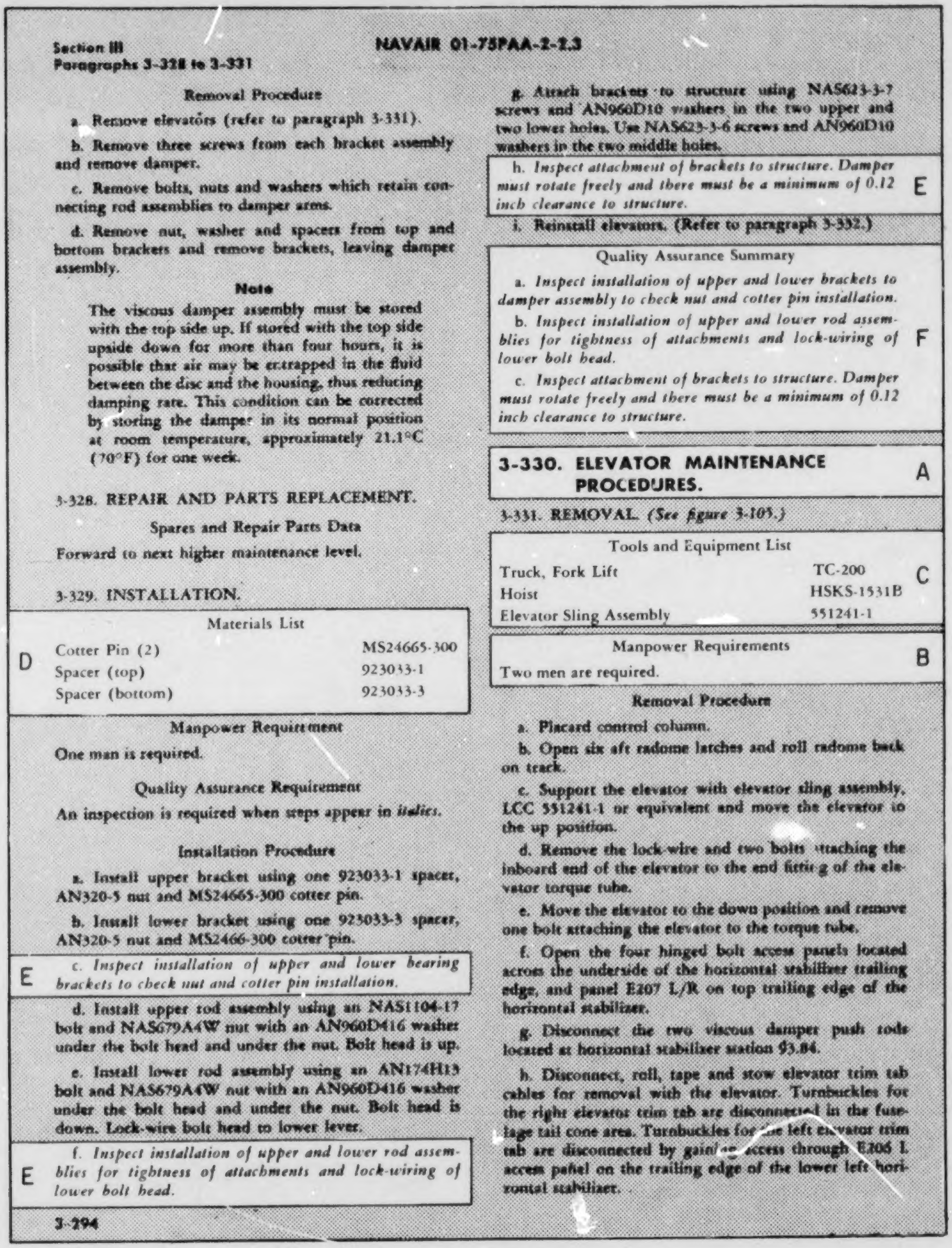
Section I is the same in all volumes of a particular aircraft Maintenance Instructions Manual. This section provides an introduction to the manual and usually supplies a list of the Changes applicable to the particular volume concerned.

Section II describes the system and components as well as their operation.

Section III provides such maintenance coverage as removal and installation procedures and troubleshooting charts for Organizational level of maintenance.

Section IV provides component repair procedures for the Intermediate level of maintenance.

Figure 2-2 is an example of a page from section III of a Maintenance Instructions Manual. This page shows the basic layout of the maintenance-coverage sections of the specialized type manuals. Each component maintenance procedure is identified by a boldface heading (item A, fig. 2-2) for ease in locating the material on the page. All removal and installation procedures provide a recommended man-



Section III
Paragraphs 3-328 to 3-331

NAVAIR 01-75PAA-2-2.3

Removal Procedure

a. Remove elevators (refer to paragraph 3-331).

b. Remove three screws from each bracket assembly and remove damper.

c. Remove bolts, nuts and washers which retain connecting rod assemblies to damper arms.

d. Remove nut, washer and spacers from top and bottom brackers and remove brackets, leaving damper assembly.

Note

> The viscous damper assembly must be stored with the top side up. If stored with the top side upside down for more than four hours, it is possible that air may be entrapped in the fluid between the disc and the housing, thus reducing damping rate. This condition can be corrected by storing the damper in its normal position at room temperature, approximately 21.1°C (70°F) for one week.

3-328. REPAIR AND PARTS REPLACEMENT.

Spares and Repair Parts Data

Forward to next higher maintenance level.

3-329. INSTALLATION.

Materials List

Cotter Pin (2)	MS24665-300
Spacer (top)	923033-1
Spacer (bottom)	923033-3

Manpower Requirement

One man is required.

Quality Assurance Requirement

An inspection is required when steps appear in *italics*.

Installation Procedure

a. Install upper bracket using one 923033-1 spacer, AN320-5 nut and MS24665-300 cotter pin.

b. Install lower bracket using one 923033-3 spacer, AN320-5 nut and MS2466-300 cotter pin.

c. *Inspect installation of upper and lower bearing brackets to check nut and cotter pin installation.*

d. Install upper rod assembly using an NAS1104-17 bolt and NAS679A4W nut with an AN960D416 washer under the bolt head and under the nut. Bolt head is up.

e. Install lower rod assembly using an AN174H13 bolt and NAS679A4W nut with an AN960D416 washer under the bolt head and under the nut. Bolt head is down. Lock-wire bolt head to lower lever.

f. *Inspect installation of upper and lower rod assemblies for tightness of attachments and lock-wiring of lower bolt head.*

g. Attach brackets to structure using NAS623-3-7 screws and AN960D10 washers in the two upper and two lower holes. Use NAS623-3-6 screws and AN960D10 washers in the two middle holes.

h. *Inspect attachment of brackets to structure. Damper must rotate freely and there must be a minimum of 0.12 inch clearance to structure.*

i. Reinstall elevators. (Refer to paragraph 3-332.)

Quality Assurance Summary

a. *Inspect installation of upper and lower brackets to damper assembly to check nut and cotter pin installation.*

b. *Inspect installation of upper and lower rod assemblies for tightness of attachments and lock-wiring of lower bolt head.*

c. *Inspect attachment of brackets to structure. Damper must rotate freely and there must be a minimum of 0.12 inch clearance to structure.*

3-330. ELEVATOR MAINTENANCE PROCEDURES.

3-331. REMOVAL. *(See figure 3-105.)*

Tools and Equipment List

Truck, Fork Lift	TC-200
Hoist	HSKS-1531B
Elevator Sling Assembly	551241-1

Manpower Requirements

Two men are required.

Removal Procedure

a. Placard control column.

b. Open six aft radome latches and roll radome back on track.

c. Support the elevator with elevator sling assembly, LCC 551241-1 or equivalent and move the elevator to the up position.

d. Remove the lock-wire and two bolts attaching the inboard end of the elevator to the end fitting of the elevator torque tube.

e. Move the elevator to the down position and remove one bolt attaching the elevator to the torque tube.

f. Open the four hinged bolt access panels located across the underside of the horizontal stabilizer trailing edge, and panel E207 L/R on top trailing edge of the horizontal stabilizer.

g. Disconnect the two viscous damper push rods located at horizontal stabilizer station 93.84.

h. Disconnect, roll, tape and stow elevator trim tab cables for removal with the elevator. Turnbuckles for the right elevator trim tab are disconnected in the fuselage tail cone area. Turnbuckles for the left elevator trim tab are disconnected by gaining access through E206 L access panel on the trailing edge of the lower left horizontal stabilizer.

3-294

AM.225

Figure 2-2.—Typical page of a Maintenance Instructions Manual.

power requirement (item B) for the shop chief's use in assigning personnel to perform the job. All tools and equipment other than standard tools are noted (item C) ahead of the maintenance procedure, so that these items may be drawn from the toolroom prior to starting the operation.

When consumable materials such as lubricants, lockwire, and cotter pins are required during an installation procedure, a listing of these items (item D) is made ahead of the procedural steps. Miscellaneous small parts (other than standard AN and MS hardware), which are necessary for removal and installation, also appear in the materials list.

As an aid to Quality Assurance Representatives, those steps in a procedure which require an inspection are set in in italics (items marked E). (NOTE: In some MIM's the steps in a procedure which require a Quality Assurance inspection are *underlined.)* These italicized steps are a very important feature and are summarized (item F) at the end of each procedure.

Classified maintenance information is not included in the regular volumes of the Maintenance Instructions Manual. Essential classified information is contained in separate volumes or supplements of the Maintenance Instructions Manual, which are classified "confidential." Classified volumes of the Maintenance Instructions Manual are bound in red in order that they may be readily identified. These volumes must be handled in accordance with the Department of the Navy Security Manual for Classified Information (OpNav Instruction 5510.1 Series).

Structural Repair Manual

The Structural Repair Manual is used as a guide in making structural repairs to the airframe. It contains general information such as airframe sealing, control surface rebalancing, general shop practices, damage evaluation and support of structure, and a description of the structure through the medium of indexed illustrations and repair drawings.

The Structural Repair Manual for most new aircraft is published in two volumes. This is not due to its size but is to suit its usage by different facilities. Volume I is for use at all levels of maintenance. Volume II supplements Volume I and contains information for use at Intermediate and Depot level facilities.

The Structural Repair Manual is identified by a "-3" in the manual publications code (fig. 2-1). The two volumes are further identified by an additional dash number. An example of the code for a Structural Repair Manual in current use is NA 01-75PAA-3-1. This is the code for Volume I of the Structural Repair Manual for the P-3A aircraft.

Each volume of the Structural Repair Manual is divided into sections. Section I contains information of a general nature. Each of the other sections contains information of a more specific nature. These sections cover portions of the aircraft such as wings, tail, fuselage, alighting gear, and engines. There is also a section covering typical repairs.

Before attempting to use the Structural Repair Manual, the mechanic should read the introduction to Volume I. Included in the introduction is information concerning the use of the manual. NOTE: Since the format of the various Structural Repair Manuals may differ, the instructions in the introduction may differ slightly.

The Structural Repair Manual is supplemented by the NA 01-1A Series general manuals.

Periodic Maintenance Requirements Manual

This manual contains the complete requirements for inspection of the aircraft, its components, and accessories. The inspection requirements are stated in such a manner as to establish what equipment is to be inspected, when it is to be inspected, and what conditions are to be sought. It does not contain instructions for repair, adjustment, or other means of correcting defective conditions, nor does it contain instructions for troubleshooting to find causes for malfunctioning.

Periodic Maintenance Requirements Data

The Periodic Maintenance Requirements Manuals are being replaced by periodic maintenance requirements data contained in three types of publications–Periodic Maintenance Information Cards (PMIC), Maintenance Requirements Cards (MRC), and Sequence Control Charts (SCC).

The PMIC's have a listing of items having an approved mandatory replacement interval and those items requiring scheduled removal component cards as defined in OpNav Instruction 4790.2.

They also contain a maintenance reference table that lists those publications which have been incorporated in the maintenance requirements since the last revision.

The Maintenance Requirements Cards and the Sequence Control Chart are discussed in Military Requirements for Petty Officer 3 & 2, NavPers 10056-C, Chapter 14.

Illustrated Parts Breakdown

The purpose of the Illustrated Parts Breakdown (IPB) is to assist supply, maintenance, and overhaul personnel in the identification, requisitioning, storing, and issuing of parts for the applicable aircraft.

The IPB for older aircraft, like the Maintenance Instructions Manual, may be found in one volume. The IPB prepared for current production aircraft contains several volumes, which usually correspond to the volumes in the Maintenance Instructions Manual.

The IPB, like the Maintenance Instructions Manual, has a code number. A "-4" in part III of the publications code (fig. 2-1) identifies the IPB. The individual volumes of the IPB are identified by an additional dash and number. An example of the code number for an IPB in current use is NA 01-60ABC-4-3. This is the code number for the Mechanical Controls volume of the RA-5C IPB.

Each volume of the IPB is divided into at least two sections and sometimes three–Section I, Introduction, Section II, Group Assembly Parts List, and Section III, when used, Numerical Index. The Introduction (Section I) contains detailed instructions for the use of the IPB. Section II includes illustrations of all parts of the applicable aircraft and its systems, equipment, and special support equipment subject to separate maintenance.

The latest type IPB has a separate volume for the Numerical Index. The Numerical Index contains an alphanumeric listing of all the parts in the IPB or volume. In addition to the part numbers, the Numerical Index contains such information as federal stock number data, figure and index numbers, source code data, and recoverability information.

The number of IPB manuals for some aircraft are numerous and for this reason some of the aircraft manufacturer's have published a Master Locator Index in conjunction with their IPB. This Master Locator Index is used to locate the IPB manual in which the part number is shown when only the part number is known. Most Master Locator Index pages are divided into 4 columns, each containing a part number and a manual number column. The number shown in the "Manual Number" column is the last dash number of the NavAir IPB manual in which the part will be found. Example: Part No. 128B10855, for an A-6A Aircraft, listed in the Master Locator Index, shows a "3" in the "Manual Number" column. This means that complete information on the part will be found in A-6A IPB, NavAir 01-85ADA-4-3. Once directed to a specific volume of the IPB the part can be further traced through the use of that volume's numerical index.

Prior to using any volume of the IPB, all of the information in Section I should be read. The information contained in this section will aid the AMS in locating the necessary part or parts quickly and easily.

Technical Manual of Weight and Balance Data

This manual provides a standard system for field weight and balance control of certain aircraft. The forms, charts, and records in this manual are prepared by the manufacturer prior to delivery of the aircraft to the Navy and provide the means of maintaining a continuous and current record of the basic weight and balance and loading information during the aircraft's service life.

Procedures and instructions for maintaining the weight and balance records are contained in the manual. These records must be maintained by operating and overhaul activities and must be brought up to date prior to transfer of the aircraft. The manual must be retained in the aircraft at all times.

General Aircraft Manuals (01 Series)

To avoid confusion between the General Manuals (00 series) and general Aircraft Manuals (01 series), an explanation is in order at this point. This chapter is concerned with AERONAUTIC publications. There are many general aeronautic publications that do not directly concern aircraft; these are in the 00 series. There are other manuals that are applicable to aircraft in general without being identified with a specific model; these are general AIRCRAFT manuals. Some general aircraft manuals with which the AMS works are as follows:

NA 01-1A-1, General Manual for Structural Repair.

NA 01-1A-8, Aircraft Structural Hardware for Aircraft Repair.

NA 01-1A-509, Aircraft Cleaning and Corrosion Control for Organizational and Intermediate Maintenance Levels.

ACCESSORIES MANUALS (03 SERIES)

The 03 series manuals cover all types of accessories. An accessory is defined as any item of equipment which is required for operation of the aircraft and which cannot be considered an integral part of the airframe or engine. Examples of accessories for which the AMS is responsible are aircraft wheels and helicopter rotor components.

The manufacturer of each item of equipment (wheels, valves, cylinders, etc.) is required to provide adequate instructions for operating the item and maintaining it throughout its service life. Accessories Manuals therefore contain descriptive data; detail instructions for installation, operation, inspection, maintenance, and overhaul; and an illustrated parts list. All Accessories Manuals available for issue are listed in numerical order (by publication number) in the Accessories Section of Part C, Section VIII of NavSup Publication 2002. They are also listed in 00-500A, but in alphanumeric order according to part number. In 00-500B, Accessories Manuals are listed under the aircraft in which the accessory is installed.

Accessories Manuals are used to supplement information found in the aircraft Maintenance Instructions Manual. For example, when the Maintenance Instructions Manual does not give instructions for repairing a particular item, reference should be made to the applicable Accessories Manual.

If an accessory is relatively simple, all the necessary instructions may be contained in a single manual. An example is NA 03-25BA-19, Overhaul Instructions with Illustrated Parts Breakdown for a landing gear wheel manufactured by the B. F. Goodrich Company.

More complex accessories may require two or more manuals. For example, one manual may cover operation, service, and overhaul instructions, while the parts breakdown is contained in a separate manual.

To determine what manuals are available for a particular accessory, proceed as follows:

If the name of the manufacturer and the model/part number of the item are known, turn to the alphanumeric part number listing in NavAir 00-500A and locate the item. All manuals applicable to that particular item of equipment will be listed by code number along with the item nomenclature.

SUPPORT EQUIPMENT MANUALS (17, 18, AND 19 SERIES)

The manufacturer of each item of support equipment is required to furnish adequate instructions for operating the equipment and maintaining it throughout its service life. Like aircraft Maintenance Instructions Manuals and Accessories Manuals, these publications prepared by the manufacturer are issued under the authority of the Naval Air Systems Command and are then official Navy publications.

The 17 and 18 series of aeronautic manuals provide information and instructions for most tools, machinery, and test equipment used in support of aircraft and components. Each item is covered by a manual which contains the purpose, procedures for preparing the item for use, operation, inspection, maintenance, lubrication, troubleshooting, and other pertinent data.

The 19 series manuals contain information on ground servicing and automotive equipment related to performing aircraft maintenance.

Support Equipment Manuals are stocked, cataloged, listed, and located in the same manner as Accessories Manuals.

NOTE: Ground support equipment data formerly provided as Descriptive Data Sheets (20 Series publications) are now identified as Ground Support Equipment Illustrations (GSEI). This information is coordinated with other branches of the service and is published and identified as MIL-HDBK-300.

SAFETY PRECAUTIONS MANUAL (NAVMAT P-5100 SERIES)

The safety precautions contained in this manual are applicable to all Navy personnel, military and civilian, and to all naval commands and activities. They are of necessity basic and general in nature and are not inclusive of all conceivable operations and functions involved in the great variety of Navy activities. In many instances references are made to other publications for detailed safety precautions applicable to specific conditions. A lack of documented hazards and pertinent precautions is not to be construed as an indication of their nonexistence or unimportance; therefore, the continuous cooperation and vigilance of all personnel is needed to see that all operating procedures and work methods do not unnecessarily expose personnel to injury or property to loss or damage.

Safety precautions shall be posted in a conspicuous place on or near any equipment, component, or material which presents a hazard to the security of the activity or to the safety of personnel. For example, those precautions necessary for the safe handling, stowage, and security of dangerous materials such as explosives or flammables shall be posted at or near the storage spaces designated for those materials.

Each individual is responsible for knowing, understanding, and observing all safety precautions applicable to his work and work area.

All chapters of the Safety Precautions Manual are extremely important; and the AMS should be especially concerned with the chapter titled Aviation. This chapter covers general precautions applicable to the maintenance, repair, and overhaul of aircraft.

TECHNICAL INFORMATION FILE OF GROUND SUPPORT EQUIPMENT (MIL-HDBK-300B)

This publication is intended to provide, in concise and convenient form, factual pictorial and descriptive data to familiarize designers, engineering, maintenance and training personnel and Government contractors with the characteristics, performance capability and physical makeup of the ground support equipment presently in the inventory of the military services and under development for use with aircraft and missile systems. In the case of Government contractors, the data sheets are intended to provide sufficient information for determining that an item of equipment is suitable or unsuitable for a contemplated application. This will insure the following:

1. Maximum usage of in-service assets.
2. Elimination of duplicate design or development of ground support equipment for different weapon systems.

This handbook contains information on ground support equipment for aircraft and missile weapon systems. Ground support equipment is construed to include ground operation, handling, and servicing equipment. Ground support equipment is further defined as all equipment required on the ground to make a weapon system operational in its intended environment.

Data sheets for the Technical Information File (TIF) will normally be selected or submitted only for ground support equipment items that have a unit cost of $1,000 and over or a potential or actual procurement total dollar value in excess of $100,000, regardless of unit cost.

Data sheets will not normally be acquired or submitted for common tools or power tools normally found in a standard machine shop; component parts or sub-assemblies of end items; kits, sets of tools, fixtures for manufacturing in depot use; sling, adapters, small containers, cabinets; or obsolete items of supply.

This handbook supersedes individual descriptive data sheets which were previously issued separately for each item of support equipment not covered by an individual technical manual.

LETTER TYPE PUBLICATIONS

TECHNICAL DIRECTIVES

The Technical Directive (TD) System has been established for control and issue of all technical directives. This system standardizes the method of issuance for such directives and is the authorized means for directing the accomplishment and recording of modifications and one-time inspections to equipment procured by and for the NavAirSysCom. The TD system is an important element in the programs designed to maintain equipment in a configuration which provides the optimum conditions of safety, operational, and material readiness. The system encompasses two types of technical directives differentiated by their method of dissemination. These two types are Formal (letter type) and Interim (message type). In general terms, they are both considered as letter type technical directives. Such directives contain instructions or information of a technical nature which cannot be satisfactorily disseminated by revisions or changes to technical manuals. This information is disseminated in the form of Changes, or in the case of special circumstances, by Interim Changes or Bulletins.

A formal TD is a document issued as a Change, or as an Amendment or Revision thereto, and promulgated by letter. Formal technical directives are used to direct the accomplishment and recording of modifications to weapons, weapons systems, support equipment, trainers, and related equipment and are comprised of Changes and Amendments and/or Revisions thereto.

An interim TD is a document issued as a Bulletin or a Change, or as an Amendment or Revision thereto, and promulgated by message to insure speedy dissemination. The interim TD is reserved for those instances requiring immediate correction of an operational or safety condition which embodies risks calculated to be intolerable within the lead time of a formal directive or maintenance publication change. Interim Changes are superseded by a Formal Change directive which will have the same number as the interim directive. Interim Bulletin directives are not superseded by formal Bulletins as was previously the case. The NavSup Publication 2002, Section VIII, Part D, will still have many formal Bulletins listed until they are eventually phased out.

A Change is a document containing instructions and information which directs the accomplishment and recording of a material change, a repositioning, a modification, or an alteration in the characteristics of the equipment to which it applies. A Change is issued to direct that parts be added, removed, or changed from the existing configuration or that parts or material be altered, relocated, or repositioned.

A Change may be issued in parts to accomplish distinct parts of a total directed action or to accomplish action on different configurations of affected equipment. A Change may also be issued for record purposes. A Record Purpose Change is a TD issued to provide documentation of a modification which has been completely incorporated by the contractor or inhouse activity in all accepted equipment and which does not require retrofit or the modification of repairables in the Navy's possession.

An Amendment is a document comprised of information which clarifies, corrects, adds to, deletes from, makes minor changes in requirements to, or cancels an existing technical directive. It is only a supplement to the existing directive and not a complete directive in itself. A maximum of three Amendments may be applied to any TD, each remaining in effect until rescinded or superseded by a Revision. A requirement for further amendment action necessitates the issuance of a Revision.

A Revision is a completely new edition of an existing technical directive. It supersedes the original directive or revision and all existing Amendments.

A Bulletin is an interim document comprised of instructions and information which directs an initial inspection to determine whether a given condition exists. It specifies what action is to be taken if a given condition is found or not found.

Interim Bulletin directives are self-rescinding with rescission dates of 30 June or 31 December, whichever is appropriate for the case at hand. Rescission is the process by which the TD's are removed from active files after all requirements have been incorporated. Final rescission action is directed in the TD Index, NavSup Publication 2002, Section VIII, Part D. All activities maintaining active technical libraries must maintain the TD's on file until they are deleted from the TD Index.

Cancellation of a technical directive is the process whereby the TD is removed from the active files when it is determined that a previously issued TD is not to be incorporated. Cancellation is directed by the issuance of an Amendment to the TD. The cancellation explicitly states the required configuration of each article initially specified for modification; for example, whether installed modifications are to remain installed or are to be removed, etc.

The title subject of a Change or Bulletin will be one of the following, as appropriate:

Airframe.
Powerplant.
Avionics.
Accessory.
Aviation Armament.
Aircrew System.
Propeller.
Photographic.
Support Equipment.
Airborne Weapon.
Clothing and Survival Equipment.
Target Control System.
Meteorological Equipment.

If the technical directive involves safety of flight, the word "SAFETY" will appear immediately following the title and number.

Technical directives are numbered by two different methods. Some are numbered consecutively from the beginning of the calendar year with the last two digits indicating the year of issue. Thus, a Change or Bulletin designated 47-54 would be the 47th change or bulletin of that type issued in 1954. This type of numbering system is no longer being used for identifying new directives. However, those which have been numbered in this manner and are still in effect are cataloged under this system.

The present numbering system is a consecutive numerical application regardless of the year of issue. For example, F-4 Airframe Change 204 would be the 204th Airframe Change that is applicable to the F-4 aircraft. This numbering system has been in effect for some time and most technical directives are cataloged under this system.

The numbers assigned to Changes and Bulletins are provided by the Technical Directives Control Center, which is located at the Naval Air Technical Services Facility (NATSF), Philadelphia. Changes or Bulletins that have been amended will have their basic number followed by the words "Amendment 1," "Amendment 2," etc. A revised directive will have the basic directive number followed with the words "Rev. A," "Rev. B," etc., as appropriate to denote the first, second, etc., revisions to that basic directive.

The Changes and Bulletins are automatically distributed to all concerned activities through inclusion on the Mailing List Request for Aeronautic Publications, NavAir Form 5605/3. All TD's are issued by NavAir or NavAirTechSerFac except in cases where the time delay in obtaining approval is unacceptable. In such cases the controlling custodians are authorized to issue interim TD's to preclude unacceptable risks to personnel or equipment. The Changes or Bulletins are generally based on Contractor Service Bulletins, other letters of recommendation, or proposed modifications from field service activities.

Directive Categories

Technical directives are assigned a "category" in accordance with the importance and urgency of accomplishing the work involved. A category of Immediate, Urgent, Routine, or Record Purposes is assigned each technical directive.

The category "Immediate Action" is assigned to directives which are issued to correct safety conditions, the uncorrected existence of which would probably result in fatal or serious injury to personnel, extensive damage, or destruction of property. Immediate Action directives involve the discontinued use of the aircraft, engines, or equipment in the operational employment under which the adverse safety condition exists, until the directive has been complied with. If the use of the aircraft, engines, or equipment will not involve the use of the affected component or system in either normal or emergency situations, compliance may be deferred, but should be accomplished no later than the next periodic inspection for the aircraft and no later than 120 days from the date of issue for the equipment. The Immediate Action directive is identified by a border of red X's broken at the top center of the page by the words "IMMEDIATE ACTION," also printed in red.

The category "Urgent Action" is assigned to directives which are used to correct safety conditions which, if uncorrected, could result in personnel injury or property damage. Such conditions compromise safety and embody risks calculated to be tolerable within narrow time limits and may or may not necessitate the imposition of operating restrictions. Urgent Action directives are identified by the words "URGENT ACTION" printed in red ink at the top of the first page and a border of red diagonals around the cover page.

The compliance requirement specifies that the incorporation of the instructions must be accomplished not later than the next regularly scheduled rework or overhaul or for equipment not reworked or overhauled on a regularly scheduled basis, not later than 18 months after the date of issuance.

Routine Action directives are issued where there are reliability, capability, or maintainability deficiencies which could, if uncorrected, become a hazard through prolonged usage or have an adverse effect on the operational life or general service utilization of equipment. The conditions embody a degree of risk or requirement determined to be tolerable within a broad time limit. The compliance requirement specifies the incorporation of the instructions not later than the next regularly scheduled overhaul or rework, or for equipment not reworked or overhauled on a scheduled basis, not later than 18 months after issuance of the directive. If accomplishment of the work requires Depot level maintenance capability, the compliance may be deferred if it will seriously interfere with operational commitments or schedules. Routeine Action directives are identified by the words "ROUTINE ACTION" printed in black capital letters at the top center of the cover page.

The category "Record Purposes" is used on a technical directive when a modification has been completely incorporated by the contractor or in-house activity in all accepted equipment and when retrofit is not required on repairables in the Navy's possession. They are identified by the words "RECORD PURPOSES" printed in black capital letters at the top center of the cover page. This type of TD merely documents the action for configuration management purposes; therefore, compliance information is not applicable and is indicated as such.

INSTRUCTIONS AND NOTICES

Instructions and Notices are directives containing information and instructions concerning policy, administration, and air operations. They are issued by all bureaus, systems commands, ships, stations, and operating activities. Those issued by the Naval Air Systems Command are known as NavAir Instructions and Notices.

Instructions are directives of a continuing nature and are effective until canceled or superseded by a later directive.

Notices are directives of a one-time nature or directives which are applicable for a brief period of time. Each Notice contains a provision for its own cancellation.

Instructions are numbered in consecutive order according to the subject covered in the Instruction. Notices are numbered according to the subject covered and serialized by the date of issue. They may be addressed to "All Ships, Stations, and Units concerned with Naval Aircraft," or to certain activities only. Each activity maintains a file of all pertinent Instructions and Notices still in effect.

MISCELLANEOUS AVIATION PUBLICATIONS

Several other unofficial publications of general interest to aviation personnel are available in most operating activities. These should be read regularly by all maintenance personnel.

NAVAL AVIATION NEWS

The Naval Aviation News, NavAir 00-75R-3, is published monthly by the Chief of Naval Operations and the Naval Air Systems Command. Its purpose is to disseminate data on aircraft training and operations, space technology, missile, rocket, and other aviation ordnance developments, aeronautical safety, aircraft design, powerplants, aircraft recognition, technical maintenance, and overhaul procedures.

As its name implies, this publication is essentially a news magazine. It enables readers to keep abreast of the latest unclassified developments in every facet of naval aviation. In addition, the coverage of fleet operations and the human interest articles on the noteworthy feats and accomplishments of individuals, both officer and enlisted, make the Naval Aviation News an entertaining as well as an informational periodical.

APPROACH

Approach, NavAir 00-75-510, The Naval Aviation Safety Review, is published monthly by the U. S. Naval Aviation Safety Center and is distributed to all naval aeronautic organizations on the basis of 1 copy for every 10 persons. It presents the most accurate information currently available on the subject of aviation accident prevention.

A large number of aviation accidents are maintenence-induced; that is, they occur during preparation for, performance of, and securing from maintenance or as a result of sloppy or improper maintenance. For instance, one fatality was reported which occurred when a maintenance man unintentionally ejected himself while arming an ejection seat. Additionally, a recent statistic reported in Approach revealed that in 9 accidents during a recent 15-month period 9 aircraft were lost–9 million dollars lost due to the omission of 9 cents worth of cotter pins.

The Approach magazine reports the results of accident investigations; and for those accidents that are maintenance-induced, describes what was done wrong and how it should have been done; suggests corrective measures to prevent future accidents resulting from these causes; and when appropriate, cites aeronautic technical publications which provide authority for changes in techniques or material to improve the maintenance product.

In short, the maintenance man who reads and heeds the messages in Approach is the man who benefits from other mechanics' experiences. Put Approach on your required reading list and look for it every month.

MECH

MECH is published quarterly by the U.S. Naval Safety Center and is distributed to naval aeronautic organizations on the basis of 1 copy per 10 persons. It presents the most accurate information available on maintenance-caused mishap prevention and general aviation ground safety. Contents are informational and should not be considered as regulations, orders, or directives. Reference to commercial products does not imply Navy endorsement.

CHAPTER 3

AIRCRAFT MATERIALS

In this chapter we will discuss the properties, characteristics, and uses of various materials used in the construction of aircraft, primarily metals and plastics. An AMS should have a knowledge and understanding of these properties, characteristics, and uses in order to inspect, maintain, and repair the airframe properly. An AMS is required to inspect metals for flaws and defects. Therefore, information on the general procedure for the inspection of metals using the dye penetrant method is also discussed.

AIRCRAFT METALS

Metallurgists have been working for more than a half century improving metals for aircraft construction. Each metal has certain properties and characteristics which make it desirable for a particular application, but it may have other qualities that are undesirable. For example, some metals are hard, others comparatively soft; some are brittle, some tough; some can be formed and shaped without fracture; and some are so heavy that weight alone makes them unsuitable for aircraft use. The metallurgist's objectives are to improve the desirable qualities and tone down or eliminate the undesirable ones. This is done by alloying (combining) of metals and by various heat-treating processes. One does not need to be a metallurgist to be a good AMS, but he should possess a knowledge and understanding of the uses, strengths, limitations, and other characteristics of aircraft structural metals. Such knowledge and understanding is vital to properly construct and maintain any equipment, especially airframes. In aircraft maintenance and repair, even a slight deviation from design specifications or the substitution of inferior materials may result in the loss of both lives and equipment. The use of unsuitable materials can readily erase the finest craftsmanship. The selection of the specific material for a specific repair job demands familiarity with the most common properties of various metals.

PROPERTIES OF METALS

This section is devoted primarily to the terms used in describing various properties and characteristics of metals in general. Of primary concern in aircraft maintenance are such general properties of metals and their alloys as hardness, malleability, ductility, elasticity, toughness, density, brittleness, fusibility, conductivity, contraction and expansion, etc. The AMS must know the definition of the terms included here as they form the basis for further discussion of aircraft metals.

Hardness

Hardness refers to the ability of a metal to resist abrasion, penetration, cutting action, or permanent distortion. Hardness may be increased by working the metal and, in the case of steel and certain titanium and aluminum alloys, by heat treatment and cold-working (discussed later). Structural parts are often formed from metals in their soft state and then heat treated to harden them so that the finished shape will be retained. Hardness and strength are closely associated properties of all metals.

Brittleness

Brittleness is the property of a metal which allows little bending or deformation without shattering. In other words, a brittle metal is apt to break or crack without change of shape. Because structural metals are often subjected to shock loads, brittleness is not a very desirable property. Cast iron, cast aluminum, and very hard steel are brittle metals.

Malleability

A metal which can be hammered, rolled, or pressed into various shapes without cracking or breaking, or other detrimental effects, is said to be malleable. This property is necessary in sheet metal which is to be worked into curved shapes such as cowlings, fairings, and wingtips. Copper is one example of malleable metal.

Ductility

Ductility is the property of a metal which permits it to be permanently drawn, bent, or twisted into various shapes without breaking. This property is essential for metals used in making wire and tubing. Ductile metals are greatly preferred for aircraft use because of their ease of forming and resistance to failure under shock loads. For this reason, aluminum alloys are used for cowl rings, fuselage and wing skin, and formed or extruded parts, such as ribs, spars, and bulkheads. Chrome-molybdenum steel is also easily formed into desired shapes. Ductility is similar to malleability.

Elasticity

Elasticity is that property which enables a metal to return to its original shape when the force which causes the change of shape is removed. This property is extremely valuable, because it would be highly undesirable to have a part permanently distorted after an applied load was removed. Each metal has a point known as the ELASTIC LIMIT beyond which it cannot be loaded without causing permanent distortion. When metal is loaded beyond its elastic limit and permanent distortion does result, it is said to have been STRAINED. In aircraft construction, members and parts are so designed that the maximum loads to which they are subjected will never stress them beyond their elastic limit. (NOTE: STRESS is the internal resistance of any metal to distortion.) This desirable property (elasticity) is present in metals used for making springs.

Toughness

A material which possesses toughness will withstand tearing or shearing and may be stretched or otherwise deformed without breaking. Toughness is a desirable property in aircraft metals.

Density

Density is the weight of a unit volume of a material. In aircraft work, the actual weight of a material per cubic inch is preferred since this figure can be used in determining the weight of a part before actual manufacture. Density is an important consideration when choosing a material to be used in the design of a part and still maintain the proper weight and balance of the aircraft.

Fusibility

Fusibility is defined as the ability of a metal to become liquid by the application of heat. Metals are fused in welding. Steels fuse around 2,500° Fahrenheit (F) and aluminum alloys at approximately 1,110°F.

Conductivity

Conductivity is the property which enables a metal to carry heat or electricity. The heat conductivity of a metal is especially important in welding, because it governs the amount of heat that will be required for proper fusion. Conductivity of the metal, to a certain extent, determines the type of jig to be used to control expansion and contraction. In aircraft, electrical conductivity must also be considered in conjunction with bonding, to eliminate radio interference. Metals vary in their capacity to conduct heat. Copper, for instance, has a relatively high rate of heat conductivity and is a good electrical conductor.

Contraction and Expansion

Contraction and expansion are reactions produced in metals as the result of heating or cooling. A high degree of heat applied to a metal will cause it to expand or become larger. Cooling hot metal will shrink or contract it. Contraction and expansion affect the design of welding jigs, castings, and tolerances necessary for hot-rolled material.

QUALITIES OF METALS

The selection of proper materials is a primary consideration in the development of an airframe and in the proper maintenance and repair of aircraft. Keeping in mind the general properties of metals, it is now possible to consider the specific requirements which metals must meet to be suitable for aircraft purposes.

Strength, weight, and reliability—these three factors determine the requirements to be met by any material used in airframe construction and repair. Airframes must be strong and also as light in weight as possible. There are very definite limits to which increases in strength can be accompanied by increase in weight. An aircraft so heavy that it could not support more than a few hundred pounds of additional weight would be of little use in this age. All metals, in addition to having a good strength/weight ratio, must be thoroughly reliable, thus minimizing the possibility of dangerous and unexpected failures. In addition to these general properties, the material selected for definite application must possess specific qualities suitable for the purpose.

In determining the most suitable material for a particular aircraft construction or repair job, the following qualities must be considered.

Strength

The material must possess the strength required by the demands of dimensions, weight, and use. There are five basic stresses which metals may be required to withstand. These are tension, compression, shear, bending, and torsion. Each is examined separately in the following paragraphs.

TENSION.—The tensile strength of a material is its resistance to a force which tends to pull it apart. Tensile strength is measured in pounds per square inch (psi) and is calculated by dividing the load, in pounds required to pull the material apart, by its cross-sectional area, in square inches. Metal being pulled is under tension.

COMPRESSION.—Compression is the opposite of tension. The compressive strength of a material is its resistance to a crushing force, which is the opposite of tensile strength. Compressive strength is also measured in psi.

SHEAR.—Shear is the tendency on the part of parallel members to slide in opposite directions. It is like placing a cord or thread between the blades of a pair of scissors. In fact, that is how shears got their name. When a piece of metal is being cut with shears, the material is subject (as it comes in contact with the cutting edges) to shear. The shear strength is the shear force in pounds per square inch at which a material fails. It is the load divided by the shear area.

BENDING.—Bending may be described as the deflection or curving of a member due to forces acting upon it. The bending strength of material is the resistance it offers to deflecting forces.

TORSION.—Torsion is a twisting force. Such action would occur in a member fixed at one end and twisted at the other. The torsional strength of material is its resistance to twisting.

Weight

The relationship between the strength of a material and its weight per cubic inch, expressed as a ratio, is known as the STRENGTH/WEIGHT RATIO. This ratio forms the basis of comparing the desirability of various materials for use in airframe construction and repair. Neither strength nor weight alone can be used as a means of true comparison. In some applications, such as the skin of monocoque structures (ch. 4), thickness is more important than strength; and in this instance, the material with the lightest weight for a given thickness or gage is best. Thickness or bulk is necessary to prevent buckling or damage caused by careless handling.

Corrosive Properties

Corrosion is the eating away or pitting of the surface or the internal structure of metals. Because of the thin sections and the safety factors used in aircraft design and construction, it would be dangerous to select a material subject to severe corrosion if it were not possible to reduce or eliminate the hazard. Corrosion can be reduced or prevented by using better grades of base metals; coating the surfaces with a thin coating of paint, tin, chromium, or cadmium; or by an electrochemical process, called anodizing. Corrosion and its control is discussed at length in chapter 11.

Working Properties

Another significant factor to consider in the selection of metals for aircraft maintenance and repair is the ability of material to be formed, bent, or machined to required shapes. The hardening of metals by cold-working or forming is termed WORK HARDENING. If a piece of metal is formed (shaped or bent) while cold, it is said to be cold-worked. Practically all the work an AMS does on metal is cold-work. While this is convenient, it causes the metal to become harder and more brittle.

If the metal is cold-worked too much (that is, if it is bent back and forth or hammered at the same place too often), it will crack or break. Usually, the more malleable and ductile a metal is, the more cold-working it can withstand.

Joining Properties

Joining metals structurally by welding, brazing, or soldering, or by such mechanical means as riveting or bolting, is a tremendous help in design and fabrication. When all other properties are equal, material that can be welded has the advantage.

Shock and Fatigue Properties

Aircraft metals are subject to both shock and fatigue (vibrational) stresses. Fatigue occurs in materials which are exposed to frequent reversals of loading or repeatedly applied loads, if the fatigue limit is reached or exceeded. Repeated vibration or bending will ultimately cause a minute crack to occur at the weakest point. As vibration or bending continues, the crack lengthens until complete failure of the part results. This is termed shock and fatigue failure. Resistance to this condition is known as shock and fatigue resistance. It is essential that materials used for critical parts be resistant to these stresses.

The preceding discussion of the properties and qualities of metals is intended to show why the AMS must know which traits in metals are desirable and which are undesirable to do certain jobs. The more one knows about a given material, the better able he is to handle it intelligently in airframe repair.

METAL WORKING PROCESSES

When metal is not cast in a desired manner, it is formed into special shapes by mechanical working processes. Several factors must be considered when determining whether a desired shape is to be cast or formed by mechanical working. If the shape is very complicated, casting will be necessary in order to avoid expensive machining of mechanically formed parts. On the other hand, if strength and quality of material are the prime factors in a given part, a casting will be unsatisfactory. For this reason, steel castings are seldom used in aircraft work.

There are three basic methods of metalworking; namely, hot-working, cold-working, and extruding. The process chosen for a particular application depends upon the metal involved and the part required, although in some instances one might employ both hot- and cold-working methods in making a single part.

Hot-Working

Almost all steel is hot-worked from the ingot into some form from which it is either hot- or cold-worked to the finished shaped. When an ingot is stripped from its mold, its surface is solid, but the interior is still molten. The ingot is then placed in a soaking pit which retards loss of heat, and the molten interior gradually solidifies. After soaking, the temperature is equalized throughout the ingot, which is then reduced to intermediate size by rolling, making it more readily handled.

The rolled shape is called a bloom when its sectional dimensions are 6 x 6 inches or larger, and approximately square. The section is called a billet when it is approximately square and less than 6 x 6 inches. Rectangular sections which have width greater than twice the thickness are called slabs. The slab is the intermediate shape from which sheets are rolled.

HOT-ROLLING.–Blooms, billets, or slabs are heated above the critical range and rolled into a variety of shapes of uniform cross section. The more common of these rolled shapes are sheet, bar, channels, angles, I-beams, and the like. In aircraft work, sheet, bar, and rods are the most commonly used items that are rolled from steel. As discussed later in this chapter, hot-rolled materials are frequently finished by cold-rolling or drawing to obtain accurate finish dimensions and a bright, smooth surface.

FORGING.–Complicated sections which cannot be rolled, or sections of which only a small quantity is required, are usually forged. Forging of steel is a mechanical working of the metal above the critical range to shape the metal as desired. Forging is done either by pressing or hammering the heated steel until the desired shape is obtained.

Pressing is used when the parts to be forged are large and heavy, and this process also replaces hammering where high-grade steel is required. Since a press is slow acting, its force is uniformly transmitted to the center of the section, thus affecting the interior grain structure as well as the exterior to give the best possible structure throughout.

Hammering can be used only on relatively small pieces. Since hammering transmits its force almost instantly, its effect is limited to a small depth. Thus, it is necessary to use a very heavy hammer or to subject the part to repeated blows to insure complete working of the section. If the force applied is too weak to reach the center, the finished forging surface will be concave. If the center is properly worked, the surface will be convex or bulged. The advantage of hammering is that the operator has control over the amount of pressure applied and the finishing temperature, and is able to produce parts of the highest grade.

This type of forging is usually referred to as smith forging and is used extensively where only a small number of parts are needed. Considerable machining and material are saved when a part is smith forged to approximately the finished shape.

Cold-Working

Cold-working applies to mechanical working performed at temperatures below the critical range and results in a strain hardening of the metal. In fact, it becomes so hard that it is difficult to continue the forming process without softening the metal by annealing.

Since the errors attending shrinkage are eliminated in coldworking, a much more compact and better metal is obtained. The strength and hardness, as well as the elastic limit, are increased, but the ductility decreases. Since this makes the metal more brittle, it must be heated from time to time during certain operations to remove the undesirable effects of the working.

While there are several cold-working processes, the two with which the AMS is principally concerned are cold-rolling and cold-drawing. These processes give the metals desirable qualities which cannot be obtained by hot-working.

COLD-ROLLING.–Cold-rolling usually refers to the working of metal at room temperature. In this operation, the materials that have been hot-rolled to approximate sizes are pickled to removed any scale, after which they are passed through chilled finished rolls. This gives a smooth surface and also brings the pieces to accurate dimensions. The principal forms of cold-rolled stocks are sheets, bars, and rods.

COLD-DRAWING.–Cold-drawing is used in making seamless tubing, wire, streamlined tie rods, and other forms of stock. Wire is made from hot-rolled rods of various diameters. These rods are pickled in acid to remove scale, dipped in lime water, and then dried in a steam room where they remain until ready for drawing. The lime coating adhering to the metal serves as a lubricant during the drawing operation. Figure 3-1 illustrates the drawing of rod, tubing, and wire.

The size of the rod used for drawing depends upon the diameter wanted in the finished wire. To reduce the rod to the desired wire size, it is drawn cold through a die. One end of the rod is filed or hammered to a point and slipped through the die opening, where it is gripped by the jaws of the draw, then pulled through the die. This series of operations is done by a mechanism known as the drawbench, as shown in figure 3-1.

In order to reduce the rod gradually to the desired size, it is necessary to draw the wire through successively smaller dies. Because each of these drawings reduces the ductility of the wire, it must be annealed from time to time before further drawings can be accomplished. Although cold-working reduces the ductility, it increases the tensile strength of the wire enormously.

In making seamless steel aircraft tubing, the tubing is cold-drawn through a ring-shaped die with a mandrel or metal bar inside the tubing to support it while the drawing operations are being performed. This forces the metal to flow between the die and the mandrel and affords a means of controlling the wall thickness and the inside and outside diameters.

Extruding

The extrusion process involves the forcing of metal through an opening in a die, thus causing the metal to take the shape of the die opening. Some metals such as lead, tin, and aluminum may be extruded cold; but generally, metals are heated before the operation is begun.

The principal advantage of the extrusion process is in its flexibility. Aluminum, because of its workability and other favorable properties, can be economically extruded to more intricate shapes and larger sizes than is practicable with many other metals. Extruded shapes are produced in very simple as well as extremely complex sections.

A cylinder of aluminum, for instance, is heated to 750° to 850°F and is then forced through the opening of a die by a hydraulic ram. Many structural parts, such as stringers, are formed by the extrusion process.

HEAT TREATMENT

Heat treatment is a series of operations involving the controlled heating and cooling of a metal in its solid state. Heat treating is for the purpose of obtaining or restoring certain desired characteristics or conditions so that the metal will be more suitable for a specific use. By heat treating, a metal may be made harder, stronger, and more resistant to impact. Heat treating can also make a metal softer and more ductile. No one heat-treating operation can produce all of these characteristics. In fact, some properties are often improved at the expense of others. For example, in being hardened, a metal may become brittle.

All of the heat-treating processes are similar in that they involve three steps—heating the metal to a specific temperature, holding or soaking at the specified temperature for a definite period, and cooling. They differ, however, in the temperatures to which the metal is heated, the time at temperature, the rate at which it is cooled, and, of course, in the final result.

The most common forms of heat treatment for ferrous metals (metals containing an iron base) are hardening, tempering, normalizing, annealing, and casehardening. Most nonferrous metals (aluminum, magnesium, titanium, copper etc.) can be annealed and many of them can be hardened by heat treatment. An AMS should have a general understanding of the following heat-treating terms, definitions, and processes.

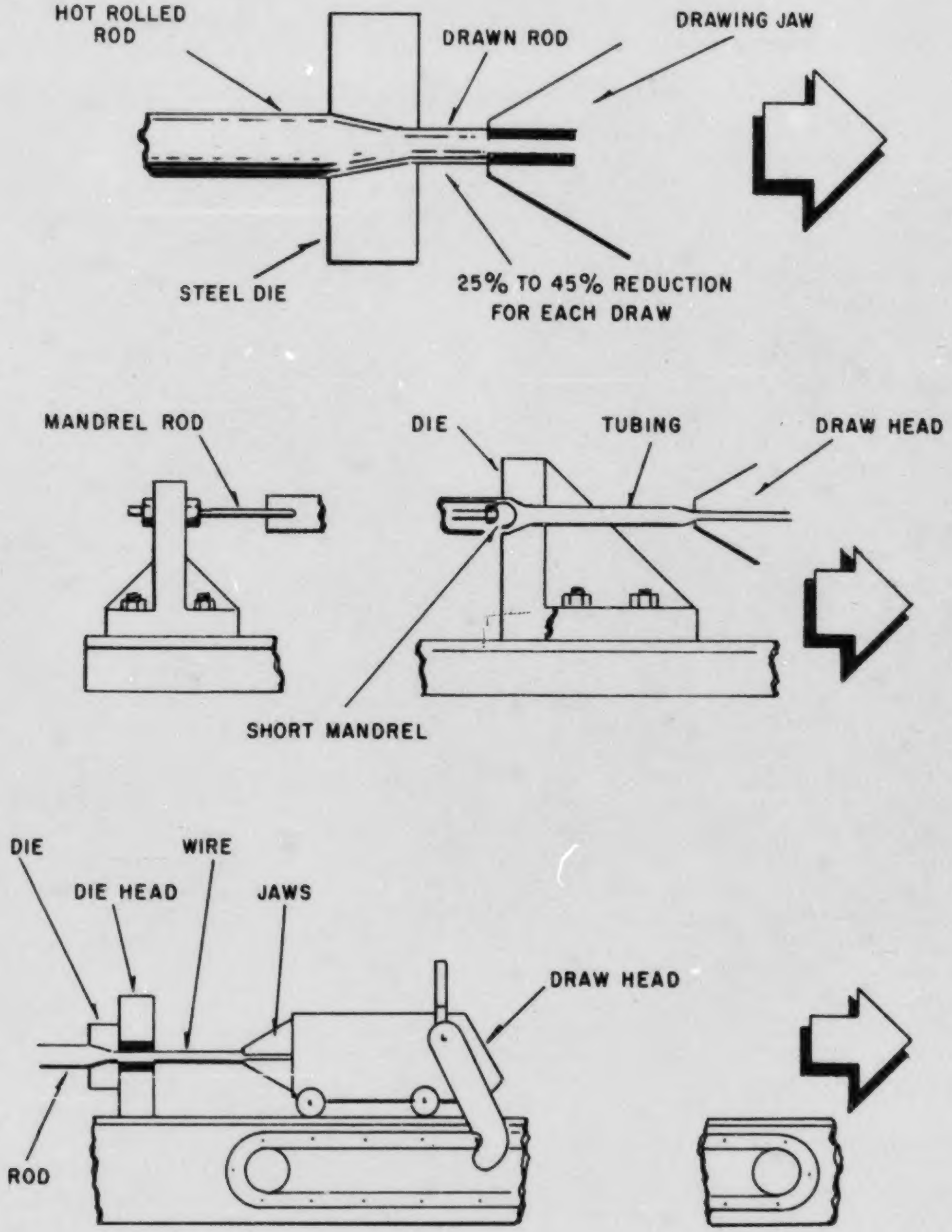
ANNEALING is a heat-treating operation in which a metal is heated to a temperature above its recrystallization point and is then cooled slowly. Its purpose may be to induce softness, alter ductility, or refine the grain size of the metal. During annealing, the metal is usually cooled in a furnace, or is packed in insulating material to retard cooling.

CASEHARDENING is a heat-treating operation in which the surface of the metal is made hard and wear resistant while the interior remains relatively soft and tough. In this operation, the surface of the metal is altered in composition by adding carbon, nitrogen, or a combination of both.

CRITICAL TEMPERATURE RANGE is the temperature at which a ferrous metal undergoes a change in internal structure while being heated or cooled (also called transformation range.)

NORMALIZING is a heat-treating operation involving the heating of a ferrous metal above its critical temperature range and cooling it in still air for the purpose of removing stresses.

PRECIPITATION HEAT TREATMENT is an aging treatment for nonferrous alloys, usually performed at room or slightly elevated temperatures. Certain aluminum alloys are given this



AM.227

Figure 3-1.—Cold-drawing operations for rod, tubing, and wire.

treatment following the solution heat treatment.

QUENCHING is the cooling of a metal from a relatively high temperature by immersing it in a cooling medium. The cooling medium may be water, oil, or air.

RECRYSTALIZATION POINT is the temperature at which the grains in a metal recrystalize or re-form into very small crystals.

SOAKING refers to holding a metal at a required temperature for a specified time to obtain an even temperature throughout the section.

SOLUTION HEAT TREATMENT is a heat treatment for nonferrous alloys in which the alloy is heated to a specified temperature (below the melting point), is held at this temperature for the required length of time, and is then quenched. The purpose of this treatment is to cause as much of the alloying constituents as possible to go into solid solution and to retain this condition by quenching.

TEMPER DESIGNATION is a term which refers specifically to nonferrous alloys. It consists of letters or letters and numbers which show the condition of the alloy and the heat treatment it has had. The temper designation is usually printed on the surface of the metal.

TEMPERING is a heat-treating operation in which hardened steel is partially annealed and the desired mechanical properties induced by reheating the metal to a temperature below its critical point.

ALLOYING OF METALS

A substance that possesses metallic properties and is composed of two or more chemical elements, of which at least one is a metal, is called an ALLOY. The metal present in the alloy in the largest proportion is called the BASE METAL. All other metals and/or elements added to the alloy are called ALLOYING ELEMENTS. The metals are dissolved in each other while molten, and they do not separate into layers when the solution solidifies. Practically all the metals used in aircraft are made up of a number of alloying elements.

Alloying elements, either in small or in large amounts, may result in a marked change in the properties of the base metal. For example, pure aluminum is a relatively soft and weak metal, but by adding small amounts of other elements such as copper, manganese, magnesium, zinc, and the like, its strength can be increased many times. Aluminum containing such other elements purposely added during manufacture is called an aluminum alloy.

In addition to increasing the strength, alloying may change the heat-resistant qualities of a metal, its corrosion resistance, electrical conductivity, or magnetic properties. It may cause an increase or decrease in the degree to which hardening occurs after cold-working. Alloying may also make possible an increase or decrease in strength and hardness by heat treatment. Alloys are, therefore, of great importance to the aircraft industry in providing materials with properties that pure metals alone do not possess.

FERROUS AIRCRAFT METALS

A wide variety of materials is required in the repair of aircraft. This is a result of the varying needs with respect to strength, weight, durability, and resistance to deterioration of specific structures or parts. In addition, the particular shape or form of the material plays an important role. In selecting materials for aircraft repair, these factors plus many others are considered in relation to their mechanical and physical properties. Among the common materials used are ferrous metals. The term FERROUS applies to the group of metals having iron as their principal constituent.

Identification

If carbon is added to iron, in percentages ranging up to approximately 1.00 percent, the product will be vastly superior to iron alone and is classified as carbon steel. Carbon steel forms the base of those alloy steels produced by combining carbon with other elements known to improve the properties of steel. A base metal (such as iron) to which small quantities of other metals have been added is called an ALLOY. The addition of other metals is to change or improve the chemical or physical properties of the base metal.

SAE NUMERICAL INDEX.–The steel classification of the Society of Automotive

Engineers (SAE) is used in specifications for all highgrade steels used in automotive and aircraft construction. A numerical index system identifies the composition of SAE steels.

Each SAE number consists of a group of digits, the first of which represents the type of steel; the second, the percentage of the principal alloying element; and usually the last two or three digits the percentage, in hundredths of 1 percent, of carbon in the alloy. For example, the SAE number 4150 indicates a molybdenum steel containing 1 percent molybdenum and 50 hundredths of 1 percent of carbon. Refer to the SAE numerical index shown in table 3-1 to see how the various types of steel are classified into four-digit classification numbers.

Table 3-1.—SAE numerical index.

Type of steel	Classification
Carbon	1xxx
Nickel	2xxx
Nickel-chromium	3xxx
Molybdenum	4xxx
Chromium	5xxx
Chromium-vanadium	6xxx
Tungsten	7xxx
Silicon-manganese	9xxx

HARDNESS TESTING METHODS.—Hardness testing is a factor in the determination of the results of heat treatment as well as the condition of the metal before heat treatment. There are two commonly used methods of hardness testing, the BRINELL and the ROCKWELL tests. These tests require the use of specific machines and are not covered in this training manual. (A knowledge of hardness testing procedures is a requirement for E-6.) An additional somewhat indirect method (SPARK TESTING) is used in identifying ferrous metals, this identification, in turn, giving some indication of the hardness of the metal.

Spark testing is a common means of identifying ferrous metals which have become mixed. In this test the piece of iron or steel is held against a revolving stone and the metal is identified by the sparks thrown off. Each ferrous metal has its own peculiar spark characteristics. The spark streams vary from a few tiny shafts to a shower of sparks several feet in length. Few nonferrous metals give off sparks when touched to a grinding stone. Therefore, these metals cannot be successfully identified by the spark test.

Wrought iron produces long shafts that are dull red colored as they leave the stone and end up a white color. Cast iron sparks are red as they leave the stone and turn to a straw color. Low-carbon steels give off long straight shafts having a few white sprigs. As the carbon content of the steel increases, the number of sprigs along each shaft increases and the stream becomes whiter in color. Nickel steel causes the spark stream to contain small white blocks of light within the main burst.

Types, Characteristics, and Uses of Alloyed Steels

While steel of the plain carbon type remains the principal product of the steel mills, so-called alloy or special steels are being turned out in ever increasing tonnage. Let us now consider those alloyed steels and their uses in aircraft.

CARBON STEELS.—Steel containing carbon in percentages ranging from 0.10 to 0.30 percent are classed as LOW–CARBON STEEL. The equivalent SAE numbers range from 1010 to 1030. Steels of this grade are used for making such items as safety wire, certain nuts, cable bushings, and threaded rod ends. Low-carbon steel in sheet form is used for secondary structural parts and clamps, and in tubular form for moderately stressed structural parts.

Steels containing carbon in percentages ranging from 0.30 to 0.50 percent are classed as MEDIUM-CARBON STEEL. This steel is especially adaptable for machining or forging and where surface hardness is desirable. Certain rod ends and light forgings are made from SAE 1035 steel.

Steel containing carbon in percentages ranging from 0.50 to 1.05 percent are classed as HIGH-CARBON STEEL. The addition of other elements in varying quantities adds to the hardness of this steel. In the fully heat-treated condition it is very hard and will withstand high shear and wear and have little deformation. It has limited use in aircraft. SAE 1095 in sheet form is used for making flat springs, and in wire form for making coil springs.

NICKEL STEELS.—The various nickel steels are produced by combining nickel with carbon steel. Steels containing from 3 to 3.75 percent nickel are commonly used. Nickel increases the hardness, tensile strength, and elastic limit of steel without appreciably decreasing the ductility. It also intensifies the hardening effect of heat-treatment. SAE 2330 steel is used extensively for aircraft parts such as bolts, terminals, keys, clevises, and pins.

CHROMIUM STEELS.—Chromium steels are high in hardness, strength, and corrosion-resistant properties. SAE 51335 is particularly adaptable for heat-treated forgings which require greater toughness and strength than may be obtained in plain carbon steel. It is used for such articles as the balls and rollers of antifriction bearings.

CHROME-NICKLE OR STAINLESS STEELS.—These are corrosion-resisting metals. The anticorrosive degree is determined by the surface condition of the metal as well as by the composition, temperature, and concentration of the corrosive agent.

The principal part of stainless steel is chromium, to which nickel may or may not be added. The corrosion-resisting steel most often used in aircraft construction is known as 18-8 steel because of its content of 18 percent chromium and 8 percent nickel. One of the distinctive features of 18-8 steel is that its strength may be increased by cold-working.

Stainless steel may be rolled, drawn, bent, or formed to any shape. Because these steels expand about 50 percent more than mild steel and conduct heat only about 40 percent as rapidly, they are more difficult to weld. Stainless steel, with but a slight variation in its chemical composition, can be used for almost any part of an aircraft. Some of its more common applications are in the fabrication of exhaust collectors, stacks and manifolds, structural and machined parts, springs, castings, and tie rods and cables.

CHROME-VANADIUM STEELS.—These are made of approximately 0.18 percent vanadium and about 1.00 percent chromium. When heat treated, they have strength, toughness, and resistance to wear and fatigue. A special grade of this steel in sheet form can be cold-formed into intricate shapes. It can be folded and flattened without signs of breaking or failure. SAE 6150 is used for making springs; and chrome-vanadium with high-carbon content, SAE 6195, is used for ball and roller bearings.

CHROME-MOLYBDENUM STEELS.—Molybdenum in small percentages is used in combination with chromium to form chrome-molybdenum steel which has various uses in aircraft. Molybdenum is a strong alloying element, only 0.15 to 0.25 percent being used in the chrome-molybdenum steels; the chromium content varies from 0.80 to 1.10 percent. Molybdenum raises the ultimate strength of steel without affecting ductility or workability. Molybdenum steels are tough, wear-resistant, and harden throughout from heat treatment. They are especially adaptable for welding, and for this reason are used principally for welded structural parts and assemblies. SAE 4130 is used for parts such as engine mounts, nuts, bolts, gear structures, support brackets for accessories and other structural parts.

The progress of jet propulsion in the field of naval aviation has been aided by the continuous research in high-temperature metallurgy. This research has brought forth alloys to withstand the high temperatures and velocities encountered in jet power units. These alloys are chemically similar to the previously mentioned steels, but may also contain cobalt, copper, and columbium in varied amounts as alloying elements.

NONFERROUS AIRCRAFT METALS

The term NONFERROUS refers to all metals which have elements other than iron as their principal constituent. This group includes aluminum, titanium, copper, and magnesium and their alloys; and in addition, such alloy metals as monel and babbitt.

Aluminum and Aluminum Alloys

Commercially pure aluminum is a white, lustrous metal, light in weight and corrosion resistant. Aluminum combined with various percentages of other metals (generally copper, manganese, magnesium, and chromium) form the alloys which are used in aircraft construction. Aluminum alloys in which the principal alloying ingredients are either manganese, magnesium, or chromium, or magnesium and silicon show little attack in corrosive environments. On the other hand, those alloys in which substantial percentages of copper are used are more susceptible to corrosive action. The total percentage of alloying elements is seldom more than 6 or 7 percent in the wrought aluminum alloys.

TYPES, CHARACTERISTICS, AND USES.–Aluminum is one of the most widely used metals in modern aircraft construction. It is vital to the aviation industry because of its high strength/weight ratio, its corrosion-resisting qualities, and its comparative ease of fabrication. The outstanding characteristic of aluminum is its light weight. In color, aluminum resembles silver although its possesses a characteristic bluish tinge of its own. Commercially pure aluminum melts at the comparatively low temperature of 1,220°F. It is nonmagnetic and is an excellent conductor of electricity.

Commercially pure aluminum has a tensile strength of about 13,000 psi, but by rolling or other cold-working processes its strength may be approximately doubled. By alloying with other metals, together with the use of heat-treating processes, the tensile strength may be raised to as high as 96,000 psi, or to well within the strength range of structural steel.

Aluminum alloy material, although strong, is easily worked, for it is very malleable and ductile. It may be rolled into sheets as thin as 0.0017 inch or drawn into wire 0.004 inch in diameter. Most aluminum alloy sheet stock used in aircraft construction ranges from 0.016 to 0.096 inch in thickness; however, some of the larger aircraft use sheet stock which may be as thick as 0.356 inch.

One disadvantage of aluminum alloy is the difficulty of making reliable soldered joints. Oxidation of the surface of the heated metal prevents soft solder from adhering to the material; therefore, to produce good joints of aluminum alloy, a riveting process is used. Some aluminum alloys are also successfully welded.

The various types of aluminum may be divided into two classes–CASTING ALLOYS (those suitable for casting in sand, permanent mold, and die castings) and the WROUGHT ALLOYS (those which may be shaped by rolling, drawing, or forging). *Of the two, the* wrought alloys are the most widely used in aircraft construction, being used for stringers, bulkheads, skin, rivets, and extruded sections. Casting alloys are not so extensively used in aircraft.

WROUGHT ALLOYS.–Wrought alloys are divided into two classes–nonheat treatable and heat treatable. In the nonheat-treatable class, strain hardening (cold-working) is the only means of increasing the tensile strength. Heat-treatable alloys may be hardened by heat treatment, by cold-working, or by the application of both processes.

Aluminum products are identified by a universally used designation system. Under this arrangement, wrought aluminum and wrought aluminum alloys are designated by a four-digit index system.

The first digit of the designation indicates the major alloying element or alloy group, as shown in table 3-2. Thus 1xxx indicates aluminum of 99.00 percent or greater, 2xxx indicates an aluminum alloy in which copper is the major alloying element, 3xxx indicates an aluminum alloy with manganese as the major alloying element, etc. Although most aluminum alloys

Table 3-2.–Designations for aluminum alloy groups.

Aluminum—99.00 percent minimum and greater	1xxx
Aluminum alloys, grouped by major alloying element:	
Copper	2xxx
Manganese	3xxx
Silicon	4xxx
Magnesium	5xxx
Magnesium and silicon	6xxx
Zinc	7xxx
Other elements	8xxx

contain several alloying elements, only one group (6xxx) designates more than one alloying element.

In the lxxx group the second digit in the designation indicates modifications in impurity limits. If the second digit is zero, it indicates that there is no special control on individual impurities. The last two of the four digits indicate the minimum aluminum percentage. Thus, alloy 1030 indicates 99.30 percent aluminum without special control on impurities. Alloys 1130, 1230, 1330, etc., indicate the same aluminum purity with special control on one or more impurities. Likewise, 1075, 1175, 1275, etc., indicate 99.75 percent aluminum.

In the 2xxx through 8xxx groups, the second digit indicates alloy modifications. If the second digit in the designation is zero, it indicates the original alloy, while numbers 1 through 9, assigned consecutively, indicate alloy modifications. The last two of the four digits have no special significance, but serve only to identify the different alloys in the group.

The temper designation follows the alloy designation and shows the actual condition of the metal. It is always separated from the alloy designation by a dash, as shown in Table 3-3.

The letter F following the alloy designation indicates the "as fabricated" condition, in which no effort has been made to control the mechanical properties of the metal.

The letter O indicates dead soft, or annealed, condition.

The letter W indicates solution heat treated. Solution heat treatment consists of heating the metal to a high temperature followed by a rapid quench in cold water. This is an unstable temper, applicable only to those alloys which spontaneously age at room temperature. Alloy 7075 may be ordered in the W condition.

The letter H indicates strain hardened; that is, cold-worked, hand-drawn, or rolled. Additional digits are added to the H to indicate the degree of strain hardening. (See table 3-3.) Alloys in this group cannot be strengthened by heat treatment, hence the term nonheat treatable.

The letter T indicates fully heat treated. Digits are added to the T to indicate certain variations in treatment.

Greater strength is obtainable in the heat-treatable alloys. Therefore, they are used for structural purposes in aircraft in preference to the nonheat-treatable alloys. Heat-treatable alloys commonly used in aircraft construction (in order of increasing strength) are 6061, 6062, 6063, 2017, 2024, 2014, 7075, and 7178.

Alloys 6061, 6062, and 6063 are sometimes used for oxygen and hydraulic lines and in some applications as extrusions and sheet metal.

Alloy 2017 is used for rivets, stressed-skin covering, and other structural members.

Alloy 2024 is used for airfoil covering and fittings. It may be used wherever 2017 is specified, since it is stronger.

Alloy 2014 is used for extruded shapes and forgings. This alloy is similar to 2017 and 2024 in that it contains a high percentage of copper. It is used where more strength is required than that obtainable from 2017 or 2024.

Alloy 7178 is used where highest strength is necessary. Alloy 7178 contains a small amount of chromium as a stabilizing agent as does alloy 7075.

Nonheat-treatable alloys used in aircraft construction are 1100, 3003, and 5052. These alloys do not respond to any heat treatment other than a softening, annealing effect. They may be hardened only by cold-working.

Alloy 1100 is used where strength is not an important factor but where weight, economy, and corrosion resistance are desirable. This alloy is used for fuel tanks, fairings, oil tanks, and for the repair of wingtips and tanks.

Alloy 3003 is similar to 1100 and is generally used for the same purposes. It contains a small percentage of manganese and is stronger and harder than 1100, but retains enough work ability that it is usually preferred over 1100 in most applications.

Alloy 5052 is used for fuel lines, hydraulic lines, fuel tanks, and wingtips. Substantially higher strengths without too much sacrifice of workability can be obtained in 5052. It is therefore preferred over 1100 and 3003 in many applications. Table 3-4 shows the nominal chemical compositions for the wrought alloys.

Alclad is the name given to standard aluminum alloys which have been coated on both sides with a thin layer of pure aluminum. Alclad has very good corrosion-resisting qualities and is used exclusively for exterior surfaces of

Table 3-3.—Temper designations for aluminum alloys.

Designation	Condition indicated	Example
- -F	As fabricated	3003-F
-O	Fully annealed	6061-O
-W	Unstable following solution heat treatment.	7075-W
-H	Strain hardened (cold worked)	
-H1, plus one or more digits.	Strain hardened only	3003-H12
-H2, plus one or more digits.	Strain hardened and then partially annealed.	3063-H24
-H3, plus one or more digits.	Strain hardened and then stabilized	5052-H36
-T	Heat treated	
-T3	Solution heat treated and then cold worked.	2024-T3
-T4	Solution heat treated	2024-T4
-T5	Artificially aged only	6063-T5
-T6	Solution heat treated and then artificially aged.	7075-T6
-T7	Solution heat treated and then stabilized to control growth and distortion.	7075-T7
-T8	Solution heat treated, cold worked, and then artificially aged.	2024-T86
-T9	Solution heat treated, artificially aged, and then cold worked.	6061-T91
-T10	Artificially aged and then cold worked.	2014-T10

NOTE: The -T designations above may have one or more digits added to denote certain variations of the basic heat treatments described.

Table 3-4.–Chemical composition of aluminum alloys.

Alloy	Alloying elements in percent. Aluminum and normal impurities constitute remainder.					
	Silicon	Copper	Manganese	Magnesium	Chromium	Zinc
3003	0.6	0.2	1.2	–	–	0.1
2014	0.8	4.5	0.8	0.4	0.1	0.25
2017	0.8	4.0	0.5	0.5	0.1	0.25
2117	–	2.5	–	0.3	–	–
2024	0.5	4.5	0.6	1.5	0.1	0.25
5052	0.45	0.1	0.1	2.5	0.25	0.1
5056	–	–	0.1	5.2	0.1	–
6061	0.6	0.25	0.15	1.0	0.25	0.25
6062	0.6	0.25	0.15	1.0	0.06	0.25
6063	0.4	0.1	0.1	0.7	0.1	0.25
7075	0.5	1.6	0.3	2.5	0.3	5.6
7178	–	2.0	0.3	2.7	0.3	6.8

aircraft. Alclad sheet is available in all tempers of 2014, 2017, 7075, and 7178.

CASTING ALLOYS.–Aluminum casting alloys, like wrought alloys, are divided into two groups. In one, the physical properties of the alloys are determined by the elements added and cannot be changed after the metal is cast. In the other, the elements added make it possible to heat treat the casting to produce desired physical properties.

The casting alloys are identified by a letter preceding the alloy number. This is exactly opposite from the case of wrought alloys in which the letters follow the number. When a letter precedes a number, it indicates a slight variation in the composition of the original alloy. This variation in composition is made simply to impart some desirable quality. In casting alloy 214, for example, the addition of zinc, to increase its pouring qualities is designated by the letter A in front of the number, thus creating the designation A214.

When castings have been heat treated, the heat treatment and the composition of the casting are indicated by the letter T and an alloying number. An example of this is the sand casting alloy 355 which has several different compositions and tempers and is designated by 355-T6, 355-T51, and A355-T51.

Aluminum alloy castings are produced by one of three basic methods–sand mold, permanent mold, and die cast. In casting aluminum, it must be remembered that in most cases different types of alloys must be used for different types of castings. Sand castings and die castings require different types than those used in permanent molds.

SHOP CHARACTERISTICS OF ALUMINUM ALLOYS.–Aluminum is one of the most readily workable of all the common commercial metals. It can be fabricated readily into a variety of shapes by any conventional method; however, formability varies a great deal with the alloy and temper.

In general, the aircraft manufacturers form the heat-treatable alloys in the -0 or -T4 condition before they have reached their full strength. They are subsequently heat treated or aged to the maximum strength (-T6) condition before installation in aircraft. By this combination of processes, the advantage of forming in a soft condition is obtained without sacrificing the maximum obtainable strength/weight ratio.

Aluminum is one of the most readily weldable of all metals. The nonheat-treatable alloys can be welded by all methods, and the heat-treatable alloys can be successfully spot welded. The melting point for pure aluminum is 1,220°F, while various aluminum alloys melt at slightly lower temperatures. Aluminum products do not show any color changes on being heated, even up to the melting point. Riveting is the most reliable method of joining stress-carrying parts of heat-treated aluminum alloy structures.

Titanium and Titanium Alloys

Titanium and titanium alloys are used chiefly for parts which require good corrosion resistance, moderate strength up to 600°F, and light weight.

TYPES, CHARACTERISTICS, AND USES.–Titanium alloys are being used in quantity for jet engine compressor wheels, compressor blades, spacer rings, housing compartments, and airframe parts such as engine pads, ducting, wing surfaces, firewalls, fuselage skin adjacent to the engine outlet, and armor plate.

In view of titanium's high melting temperature, approximately 3,300°F, its high-temperature properties are disappointing. The ultimate and yield strengths of titanium drop fast above 800°F. In applications where the declines might be tolerated, the absorption of oxygen and nitrogen from the air at temperature above 1,000°F, makes the metal so brittle on long exposure that it soon becomes worthless. Titanium has some merit for short-time exposure up to 2,000°F where strength is not important, as in aircraft firewalls.

Sharp tools are essential in machining techniques as titanium has a tendency to resist or back away from the cutting edge of tools. It is readily welded, but the tendency of the metal to absorb oxygen, nitrogen, and hydrogen must never be ignored. Machine welding with an inert gas atmosphere has proven most successful.

Both commercially pure and alloy titanium can absorb large amounts of cold-work without cracking. Practically anything that can be deep drawn in low-carbon steel can be duplicated in commercially pure titanium, although the titanium may require more intermediate anneals.

IDENTIFICATION OF TITANIUM.–Titanium metal, pure or alloyed, is easily identified. When touched with a grinding wheel, it makes white spark traces which end in brilliant white bursts. When rubbed with a piece of glass, moistened titanium will leave a dark line similar in appearance to a pencil mark.

Copper and Copper Alloys

Most commercial copper is refined to a purity of 99.9 percent minimum copper plus silver. It is the only reddish colored metal and is second only to silver in electrical conductivity. Its use as a structural material is limited because of its great weight. However, some of its outstanding characteristics, such as its high electrical and heat conductivity, in many cases overbalance the weight factor.

Because it is very malleable and ductile, copper is ideal for making wire. In aircraft, copper is used primarily for the electrical system and for instrument tubing and bonding. It is corroded by salt water but is not affected by fresh water. The ultimate tensile strength of copper varies greatly. For cast copper, the tensile strength is about 25,000 psi; and when cold-rolled or cold-drawn, its tensile strength increases, ranging from 40,000 to 67,000 psi.

BRASS.–Brass is a copper alloy containing zinc and small amounts of aluminum, iron, lead, manganese, magnesium, nickel, phosphorous, and tin. Brass with a zinc content of 30 to 35 percent is very ductile while that containing 45 percent has relatively high strength. MUNTZ METAL is a brass composed of 60 percent copper and 40 percent zinc. It has excellent corrosion-resistant qualities when in contact with salt water. Its strength can be increased by heat treatment. As cast, this metal has an ultimate tensile strength of 50,000 psi and can be elongated 18 percent. It is used in making bolts and nuts, as well as parts that come in contact with salt water. RED BRASS, sometimes termed bronze because of its tin content, is used in fuel and oil line fittings. This metal has good casting and finishing properties and machines freely.

BRONZES.–Bronzes are copper alloys containing tin. The true bronzes have up to 25 percent tin, but those below 11 percent are most useful, especially for such items as tube fittings in aircraft.

Among the copper alloys are the copper aluminum alloys, of which the aluminum bronzes rank very high in aircraft usage. They would find greater usefulness in structures if it were not for their strength/weight ratio as compared with alloy steels. Wrought aluminum bronzes are almost as strong and ductile as medium-carbon steel and possess a high degree of resistance to corrosion by air, salt water, and chemicals. They are readily forged, hot- or cold-rolled, and many react to heat treatment.

These copper-base alloys contain up to 16 percent of aluminum (usually 5 to 11 percent) to which other metals such as iron, nickel, or manganese may be added. Aluminum bronzes have good tearing qualities, great strength, hardness, and resistance to both shock and fatigue. Because of these properties, they are used for diaphragms and gears, air pumps, condenser bolts, and slide liners. Aluminum bronzes are available in rods, bars, plates, sheets, strips, and forgings.

Cast aluminum bronzes, using about 89 percent copper, 9 percent aluminum, and 2 percent of other elements, have high strength combined with ductility, and are resistant to corrosion, shock, and fatigue. Because of these properties, cast aluminum bronze is used in gun mounts, bearings, and pump parts. These alloys are useful in areas exposed to salt water and corrosive gases.

Manganese bronze is an exceptionally high-strength, tough, corrosion-resistant copper zinc alloy containing aluminum, manganese, iron, and occasionally nickel or tin. This metal can be formed, extruded, drawn, or rolled to any desired shape. In rod form, it is generally used for machined parts. Otherwise it is used in catapults, landing gears, and brackets.

Silicon bronze is composed of about 95 percent copper, 3 percent silicon, and 2 percent manganese, zinc, iron, tin, and aluminum. Although not a bronze in the true sense of the word because of its small tin content, silicon bronze has high strength and great corrosion resistance and is used variably.

BERYLLIUM COPPER.—Beryllium copper is one of the most successful of all the copper-base alloys. It is a recently developed alloy containing about 97 percent copper, 2 percent beryllium, and sufficient nickel to increase the percentage of elongation. The most valuable feature of this metal is that the physical properties can be greatly stepped up by heat treatment—the tensile strength rising from 70,000 psi in the annealed state to 200,000 psi in the heat-treated state. The resistance of beryllium copper to fatigue and wear makes it suitable for diaphrams, precision bearings and bushings, ball cages, spring washers, and nonsparking tools.

Monel

Monel, the leading high-nickel alloy, combines the properties of high strength and excellent corrosion resistance. This metal consists of 67 percent nickel, 30 percent copper, 1.4 percent iron, 1 percent manganese, and 0.15 percent carbon. It cannot be hardened by heat treatment—responding only to cold-working.

Monel, adaptable to castings and hot- or cold-working, can be successfully welded and has working properties similar to those of steel. It has a tensile strength of 65,000 psi which, by means of cold-working, may be increased to 160,000 psi, thus entitling this metal to classification among the tough alloys. Monel has been successfully used for gears and chains, for operating retractable landing gears, and for structural parts subject to corrosion. In aircraft, monel has long been used for parts demanding both strength and high resistance to corrosion, such as exhaust manifolds and carburetor needle valves and sleeves.

K-Monel

K-monel is a nonferrous alloy containing mainly nickel, copper, and aluminum. It is produced by adding a small amount of aluminum to the monel formula. It is corrosion resistant and capable of hardening by heat treatment. K-monel has been successfully used for gears, chains, and structural members in aircraft which are subjected to corrosive attacks. This alloy is nonmagnetic at all temperatures. K-monel can be successfully welded.

Magnesium and Magnesium Alloys

Magnesium, the world's lightest structural metal, is a silvery-white material weighing only two-thirds as much as aluminum. Magnesium does not possess sufficient strength in its pure state for structural uses; but when alloyed with zinc, aluminim, and manganese, it produces an alloy having the highest strength/weight ratio.

TYPES, CHARACTERISTICS, AND USES.–Magnesium is probably more widely distributed in nature than any other metal. It can be obtained from such ores as dolomite and magnesite, from underground brines, from waste liquors of potash, and from sea water. With about 10 million pounds of magnesium in 1 cubic mile of sea water, there is no danger of a dwindling supply.

Magnesium is used extensively in the manufacture of helicopters. Its low resistance to corrosion has been a factor in reducing its use in conventional aircraft.

The machining characteristics of magnesium alloys are excellent. Usually the maximum speeds of machine tools can be used with heavy cuts and high feed rates. Power requirements for magnesium alloys are about one-sixth of those for mild steel. An excellent surface finish can be produced, and in most cases grinding is not essential. Standard machine operations can be performed to tolerances of a few ten-thousandths of an inch. There is no tendency of the metal to tear or drag.

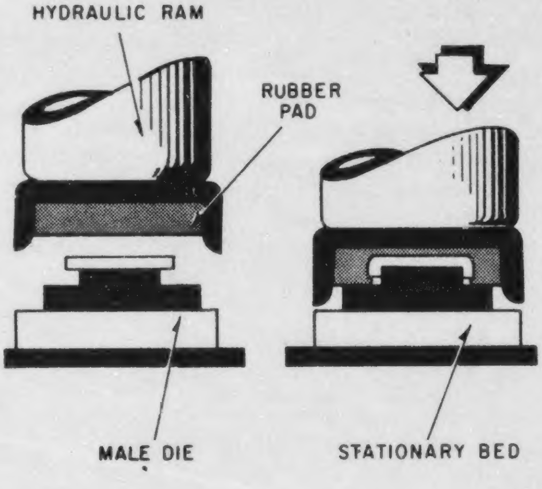
Magnesium alloy sheets can be worked in much the same manner as other sheet metal with one exception–the metal must be worked while hot. The structure of magnesium is such that the alloys work-harden rapidly at room temperatures. The work is usually done at temperatures ranging from 450° to 650°F, which is a disadvantage. However, compensations are offered by the fact that in the ranges used, magnesium is more easily formed than other materials. Sheets can be sheared in much the same way as other metals, except that a rough flaky fracture is produced on sheets thicker than about 0.064 inch. A better edge will result on a sheet over 0.064 inch thick if it is sheared hot.

Annealed sheet can be heated to 600°F, but hard rolled sheet should not be heated above 275°F. A straight bend with short radius can be made by the GUERIN PROCESS, as shown in figure 3-2, or by press or leaf brakes. The Guerin process is the most widely used method for forming and shallow drawing, employing a rubber pad as the femal die, which bends the work to the shape of the male die.

Magnesium alloys possess good casting characteristics. Their properties compare favorably with those of cast aluminum. In forging, hydraulic presses are ordinarily used; although, under certain conditions, forging can be accomplished in mechanical presses or with drop hammers.

Magnesium embodies fire hazards of an unpredictable nature. When in large sections, its high thermal conductivity makes it difficult to ignite, and prevents its burning. It will not burn until the melting point is reached, which is approximately 1,200°F. However, magnesium dust and fine chips are ignited easily. Precautions must be taken to avoid this if possible, and to extingush them immediately. An extinguishing powder, such as powdered soapstone, clean, dry, unrusted cast iron chips, or graphite powder, should be used.

CAUTION: Water or any standard liquid or foam extinguisher causes magnesium to burn more rapidly and may cause small explosions.



AM.228

Figure 3-2.–Guerin process.

SUBSTITUTION AND INTERCHANGEABILITY OF AIRCRAFT METALS

In selecting interchangeable or substitute materials for the repair and maintenance of naval aircraft, it is of the utmost importance to check the appropriate aeronautic technical publications when specified materials are not in stock nor obtainable from another source. It is impossible to determine that another material is as strong as the original by mere observation. There are four requirements that must be kept clearly in mind in this selection. The first and most important of these is maintaining the original strength of the structure. The other three are maintaining contour or aerodynamic smoothness, maintaining original weight if possible or keeping added weight to a minimum, and maintaining the original corrosive-resistance properties of the metal.

The importance of checking the specific technical publication can be appreciated by understanding that different manufacturers design structural members to meet various load requirements for specific aircraft. Structural repair of these members, apparently similar in construction, will thus vary in their load carrying design with different aircraft.

Structural repair instructions, including tables of interchangeability and substitution for ferrous and nonferrous metals and their specifications for all types of aircraft used by the Navy, are normally prepared by the contractor. Such instructions are usually promuigated in the -3 manual covering structural repair instructions for specific model of aircraft. Similar information is also contained in NavAir 01-1A-1, General Manual for Structural Repair.

NavAir 01-1A-1, section III, table IV, presents the substitution and conversion information for aluminum alloy sheet metal. In section IV, table IV, steel specifications are given; table V, in section IV, covers aluminum specifications.

NavAir 01-1A-9, Aerospace Metals–General Data and Usage Factors, provides precise data on specific metals to assist in selection, usage, and processing for fabrication and repair.

Always consult these publications and the -3 aircraft manual for the specific-type aircraft when confronted with a problem concerning maintenance and repair involving substitution and interchangeability of aircraft structural metals. BE SURE YOU HAVE THE AERONAUTIC TECHNICAL PUBLICATION OF THE MOST RECENT ISSUE.

INSPECTION OF METALS

When a metallic part is suspected of having a tiny crack or other invisible defect, it is generally inspected by one of the following methods: the penetrant method, the magnetic particle inspection method, the radiographic (X-ray) method, the eddy current method, or the ultrasonic method.

The various types and methods of penetrant inspections are suitable for locating almost any type of defect open to the surface on a variety of nonabsorbent materials such as ferrous and nonferrous metals, ceramics, hard rubber, plastic, and glass. Metals that can be magnetized (ferrous metals) are usually inspected by the magnetic particle method. The X-ray method may be used for inspecting any of the foregoing metals. All of these methods are nondestructive tests, which means they are performed on the actual part without damage to the part.

To advance to E-4, all AMS strikers must be able to perform dye penetrant inspections, and to advance from E-4 to E-5, the AMS must be able to interpret the results obtained by using the penetrant method. Coverage on other methods of inspecting metals mentioned above is not included in this chapter, as proficiency in these methods is not a requirement at this level.

The following section will provide basic coverage on the types and methods of penetrant inspection, general inspection procedures, and interpretation of results. Complete and detailed coverage necessary for a thorough understanding of the penetrant methods of inspection is provided in NavAir 01-1A-16, Nondestructive Inspection Methods, Technical Manual. Tests on critical aircraft components require a thorough knowledge of all material included in that section of the manual for the specific test being conducted to insure proper testing and interpretation.

PENETRANT INSPECTIONS

Penetrant inspection is a nondestructive test for defects open to the surface in parts made of any nonporous material. Penetrant inspection depends for its success upon a penetrating liquid entering the surface opening and remaining in that opening, making it clearly visible for the operator. It calls for visual examination of the part by the operator after it has been processed, but the visibility of the defect is increased so that it can be detected. Visibility of the penetrating material is increased by the addition of dye which may be either one of two types–visible or fluorescent.

The main disadvantage of penetrant inspection is that the defect must be open to the surface in order to let the penetrant into the defect. For this reason, if the part in question is made of material which is magnetic, the magnetic particle inspection or X-ray is generally recommended. It is also essential that there be no contaminant within the defect which might either prevent the penetrant from entering or which may reduce its visibility.

The materials used in the visible dye penetrant inspection are available in aviation supply stock in the form of a complete inspection kit. Included in the kit are the following items: two spray cans of penetrant, dye remover-emulsifier, and developer. For replenishment purposes, these materials are also available as individual items. The chemicals are available in ordinary containers for use when dipping or brushing is desired.

The fluorescent inspection materials and equipment are also furnished in kit form. The complete equipment is contained in a metallic carrying case. Included are the following items: penetrant, penetrant cleaner, penetrant developer (both powder and suspension types), dauber for applying powder, and a black light (ultra violet) assembly complete with power transformer. The chemicals may be replenished individually from aviation supply stock.

General Inspection Procedure

First of all, the part to be inspected must be clean. This includes the removal of surface dirt, scale, paint, and oil, as well as removing any materials or compounds that might fill or cover the defects. If the part has been in contact with water it may be possible to heat the part slightly to evaporate the water.

Penetrant is then applied to all surfaces. This may be done by dipping, flow-on, brushing, or spraying. It is important that all suspect areas be wet with penetrant. The penetrant must be allowed to remain on the part for a period of time called the penetration (dwell) time. This allows the penetrant to seek and fill surface openings. The length of the penetration time varies with the process and techniques used, the material of which the part is made, and the types of defects present.

The excess surface penetrant is removed from the part by means of a forceful water spray. This operation does not remove the penetrant from deep defects but does remove the penetrant on the surface.

A developer is then applied to the part before inspection. The function of the developer is to blot back to the surface the penetrant that is entrapped in fissures or defects in the part. The developer should be allowed to remain on the part for a time before inspection for defects. This elapsed time is to allow the developer to bring back to the surface and magnify the traces of penetrant. Some types of defects in some parts may be detectable without the use of a developer, but for consistent and positive results, current instructions recommend that a developer always be used. A drying operation is necessary which increases the effectiveness of the method and, depending upon the type of developer used, either dries the wet developer or prepares the part for the application of the dry developer.

After the proper developing time has elapsed, the part is ready for inspection. If the penetrant used has a fluorescent dye in it, the inspection must be performed in a darkened area and under black light. If the penetrant used has a visible die, then inspection can be performed under ordinary lighting conditions.

All traces of the developer should be removed from the part before it is returned to service.

Types of Processes

There are two types of penetrant inspection processes. Type I employs the use of fluorescent penetrants, and Type II processes employ the use of visible dye penetrants. Within each type there are three methods, which are referred to as methods A, B, and C. Each method within a type uses a specific group of materials. Table 3-5 lists the types and methods of penetrant inspection and their related group of materials.

Group I through group III penetrants are visible dye penetrants containing dyes that make them readily visible when exposed to natural or

Table 3-5.–Penetrant inspection types, methods, and material groups

Type	Method	Penetrant Used	MIL-I-25135 Material Group Used	Family of Items In Group
I	A	Water-washable fluorescent dye	Group IV	Consists of a water-washable fluorescent penetrant and a dry, wet, or nonaqueous wet developer.
I	B	Post-emulsifiable fluorescent dye.	Group V	Consists of a post-emulsifiable fluorescent penetrant, an emulsifier, and a dry, wet, or nonaqueous wet developer.
			Group VI	Consists of a high-sensitivity post-emulsifiable fluorescent penetrant, an emulsifier, and a dry, wet, or nonaqueous wet developer.
I	C	Solvent-removable fluorescent dye.	Group VII	Consists of a solvent-removable fluorescent penetrant, a penetrant remover (solvent) and a nonaqueous wet developer.
II	A	Water-washable visible dye.	Group III	Consists of a water-washable visible dye penetrant and a dry, wet, or nonaqueous wet developer.
II	B	Post-emulsified visible dye.	Group II	Consists of a post-emulsifiable visible dye penetrant, an emulsifier, and a dry, wet, or nonaqueous wet developer.
II	C	Solvent-removable visible dye.	Group I	Consists of a solvent-removable visible dye penetrant, a penetrant remover (solvent), and a dry, wet, or nonaqueous wet developer.

artificial white light. Penetrants in group I are removed by wiping with a cloth dampened by a specially prepared compatible solvent supplied with the portable penetrant kit. Penetrants in group II are water washable (for removal) after application of an emulsifier. This two-step process makes group II penetrants more suitable for detecting wide, shallow defects. Group II penetrants are referred to as post-emulsifiable penetrants. Group III penetrants contain an emulsifier which makes them water washable as furnished.

Group IV through VII penetrants contain dyes which will fluoresce (glow) when exposed to black light. Group IV penetrants contain an emulsifier which makes it water washable as furnished. Groups V and VI are water washable after application of an emulsifier the same as group II. Group VII penetrants are removed by wiping with a solvent-dampened cloth the same as group I.

Selection of Inspection Process

The selection of the best type of penetrant inspection suitable for the job at hand will depend on several factors as follows:

1. Previously established requirements specified on documents requiring the inspection.
2. Penetrant sensitivity required.
3. Surface condition of the part.
4. Configuration of the part.
5. Number of parts to be tested.
6. Facilities and equipment available.
7. Effect of the penetrant chemicals on the material being tested.

TYPE I, METHOD A, INSPECTION PROCESS.—This method lends itself to inspecting large volumes of parts, large areas, rough surfaces, and threads and keyways. It is the recommended type/method to be used when:

Discontinuities are not wider than their depth.

The lowest flourescent penetrant sensitivity is sufficient to detect the defects inherent to the part.

Removal of excess penetrant may be difficult due to rough surfaces on the part.

Sulfonates in the emulsifying agents will not affect nickel bearing steels.

NOTE: This method is not recommended for detecting extremely fine intergranular corrosion or stress corrosion defects.

The water-washable flourescent dye penetrant used in this type/method insures good visibility of flaw patterns and can be easily washed off with water. Since it is considered a one-step process, it is fast and economical in time and is relatively inexpensive to perform. This process is not reliable in finding scratches and shallow discontinuities as the penetrant is susceptible to overwashing. It is not reliable on anodized surfaces, and the penetrant can be affected by acids and chromates.

Following precleaning and drying, the water-washable fluorescent penetrant is applied to the surface being inspected by dipping, flow-on, spraying, or brushing methods. After the predetermined dwell time, it is flushed from the surface with a low-pressure (20-30 psi) spray of cold water. The developer is then applied and will cause the penetrant to bleed from any discontinuities or defects, and these flaw indications will become visible when exposed to black light.

TYPE I, METHOD B, INSPECTION PROCESS.—This method is used when inspecting large volumes of parts which may have defects that are contaminated with in-service soils or that may be contaminated with acids or other chemicals that will harm water-washable penetrants. It is the type/method recommended for use when:

A higher sensitivity than that offered by Type I, Method A, is required.

Discontinuities are wider than their depth.

Inspecting parts for stress cracks, intergranular corrosion, or grinding cracks.

Variable, controlled sensitivities are necessary so that nondetrimental discontinuities can be disregarded while harmful or detrimental ones can be detected.

The group V penetrant used with this type/method is more sensitive than the group IV penetrant of Type I, Method A; however, the group VI penetrant used with Type I, Method B, is more sensitive than group V.

NOTE: Only group VI materials are used for inspecting for stress cracks or intergranular corrosion.

The fluorescent penetrant used in this process is more brilliant than other processes and affords greater visibility when exposed to black light. For field use where light exclusion is not always possible, it provides the greatest degree of brilliance.

The Type I, Method B, process is highly sensitive to fine defects and is also good on wide, shallow defects. The penetrant washes easily after emulsification and the penetrant is not as susceptible to overwashing. Since it is considered a two-step process, because of the emulsifier, it is slower than Type I, Method A. The process is not as good on rough surfaces, keyways, or threads; and because of the extra materials used in the inspection, it is slightly more expensive.

Following precleaning and drying, the post-emulsifiable fluorescent penetrant is applied to the surface being inspected. After being allowed to dwell for the predetermined time, the emulsifier is applied. The emulsifier combines with the penetrant and is water washable. The excess penetrant is then removed using a low-pressure (30 to 40 psi) spray of cold water. The part is then thoroughly dried and the developer applied. The penetrant is then drawn to the surface and any flaw indications will become apparent as a brilliant greenish-yellow color when exposed to black light. The sensitivity of this process can be controlled by the type of penetrant used, dwell time, emulsifying time, rinsing technique, and drying temperature and time.

TYPE I, METHOD C, INSPECTION PROCESS.–This method is used for spot inspection on large or small parts where the water rinsing method is not fensible because of part size, weight, surface conditions, and lack of water, or there is no heat for drying or field use. The use of solvent required to remove the penetrant prohibits this process in inspecting large areas. Its sensitivity can also be reduced by the application of excessive amounts of penetrant remover.

Following precleaning and drying, the solvent removable fluorescent penetrant is applied to the surface being inspected by dipping, flow-on, spraying, or brushing methods. After the predetermined dwell time, it is then removed with the solvent remover. The part is thoroughly dried and developer is applied. Penetrant will bleed from any discontinuities or defects and the flaw indications will be apparent when exposed to black light.

TYPE II, METHOD A, INSPECTION PROCESS.–This process is utilized for inspecting surfaces when the circumstances described for Type I, Method A, exist and a fluorescent dye penetrant is not necessary. A black light is not needed; therefore, the work area need not be darkened. The process is relatively inexpensive, highly portable, excellent for spot checking, and can be used on anodized parts. The penetrant is easily washed off with fresh water.

Following precleaning and drying, the water-washable visible dye penetrant is applied by dipping, flow-on, spraying, or brushing methods. After the predetermined dwell time, it is flushed from the surface with a low-pressure spray of water and the surface is dried. The application of developer then draws out penetrant left in any discontinuities or defects, and these flaw indications should appear clearly against the white developer background. The indications can be easily seen in natural or artificial light.

TYPE II, METHOD B, INSPECTION PROCESS.–This method is used when a higher sensitivity than that afforded by Type II, Method A, is required. It is used when inspecting large volumes of parts, parts that are contaminated with acid or other chemicals that will harm water-washable penetrants, parts which may have defects that are contaminated with inservice soils, and for inspecting finished surfaces and other general purpose applications.

The materials in this process are the most sensitive of the visible dye penetrant inspection methods; however, it is not recommended for detecting extremely fine intergranular corrosion or stress corrosion defects.

Following precleaning and drying, the post-emulsifiable visible dye penetrant is applied to the surface being inspected by dipping, flow-on, spraying, or brushing methods. After this group II penetrant is allowed to dwell for a predetermined time, the emulsifier is applied. The emulsifier combines with the penetrant, which becomes water washable. The excess penetrant is then washed off using a low-pressure (30-40 psi) spray of cold water. Application of the desired developer will then draw out and absorb the intense red penetrant from the discontinuity to provide a clear indication against the white developer background.

TYPE II, METHOD C, INSPECTION PROCESS.–This method is used when spot inspection is required and where water rinsing is not feasible. The use of solvent in removing the penetrant prohibits inspection of large areas and the process is not adaptable for detecting extremely fine defects.

Following precleaning and drying, the solvent removable visible dye penetrant is applied as with previous methods. After the predetermined dwell time, it is removed from the surface with solvent remover and the part is thoroughly dried. The application of the developer draws out the bright red indication as with the other two visible penetrant types and methods.

EMULSIFIERS.–The emulsifiers discussed under the various types and methods are liquid additives which, when applied to post-emulsifiable penetrants, combine with the excess surface penetrant to render it water removable. These emulsifiers have low penetrating properties, a necessary feature to avoid having the emulsifier remove the penetrant from the discontinuity. They are of a contrasting color to the post-emulsifiable penetrant so that it can be determined easily if all the emulsifier has been removed during the water rinsing. Proper rinsing of fluorescent emulsifiers is checked using the black light. Emulsifier dwell time is that time which it takes for the emulsifier to mix with the surface penetrant in order for it to rinse properly.

DEVELOPERS.–As previously mentioned under the types and methods (table 3-5), there are three types of developers–dry, aqueous wet, and nonaqueous wet.

Dry developer is a highly absorptive fluffy white powder. It is applied to the part after it has been thoroughly dried and provides a contrasting background to flaw indications and absorbs the penetrant at the defect. The dry type developers cause less bleeding of the penetrant indication and thus provide better resolution. The dry developer adheres primarily to the flaw openings wetted by the penetrant liquid and provides sharp flaw delineations. It is applied by dipping, dusting, or flow-on method.

Aqueous wet developer consists of an absorbent powder supplied in dry form which is mixed and suspended in water for application to the part being penetrant inspected. The suspension of the wet developer must be agitated to insure thorough suspension of the absorbent powder in the water. Excess penetrant is removed from the part and the wet developer is applied to the part while it is still wet. The wet developer, on drying, provides an absorbent white background for maximum color contrast and causes the penetrant to bleed from the flaw cavity, obtaining increased inspection accuracy. Wet developers cause greater bleeding and are more sensitive when applied as a spray. They are applied by dipping or flow-on method.

Nonaqueous wet developer consists of an absorbent powder suspended in a volatile liquid. This developer offers the highest relative sensitivity and is used primarily for spot inspection where the surface being inspected has not been heated during the process. The sensitivity of the developer can be increased by vibrating the spray gun during application. The preferred method of application is spraying. It may also be applied by brushing, but this is not generally preferred.

NOTE: Nonaqueous developers should not be applied to a hot part until the part has been cooled enough to be hand held. Some of the nonaqueous developers have a flash point of 50°F.

Developer dwell time will depend on the type of penetrant developer and the type of defect. Allow sufficient time for an indication to form, but do not allow penetrant to bleed into the developer in such quantities to cause a loss of defined indications.

The developer dwell time will vary from a few minutes to an hour or more. A good rule of thumb is as follows: development time for a given material or type of defect is about one-half of the time considered proper for penetration dwell time.

Interpreting Results

With penetrant inspections there are no false indications in the sense that such things occur in the magnetic particle inspection. However, there are two conditions which may create accumulations of penetrant that sometimes are confused with true surface cracks.

The first condition is a result of poor washing. If all the surface penetrant is not removed in the washing or rinse operation following the penetration time, the unremoved penetrant will be visible. This condition is usually easy to identify since the penetrant will be in broad areas rather than in the sharp patterns found with true indications. When accumulations of unwashed penetrant are found on a part, the part should be completely reprocessed. Degreasing is recommended for removal of all traces of the penetrant.

Another condition which may create false indications is where parts are press-fit to each other. For example, if a wheel is press-fit onto a shaft, the penetrant will show an indication at the fit line. This is perfectly normal since the two parts are not meant to be welded together. Indications of this type are easy to identify since they are so regular in form and shape.

The success and reliability of the penetration inspection depend upon the thoroughness with which the operator prepares the part from the precleaning all the way through to the actual search for indications. It is not a method by which a part is thrown into a machine which separates the good parts from the bad. The operator must carefully process the part, search out indications, and then decide the seriousness of defects found in order to determine the disposition of parts with indications. Penetrant inspections are important tools for finding defects before those defects grow into failures. As an operator, it is up to you to get the most out of the method used.

Fluorescent indications, when viewed under black light, fluoresce brilliantly and the extent of the indication marks the extent of the defect. Pores, shrinkage, lack of bond and leaks will show as glowing spots, while cracks, laps, forging bursts or cold shuts will show as fluorescent lines. Where a large defect has trapped a quantity of penetrant the indications will spread on the surface. Experience in the use of the method allows interpretations to be drawn from the extent of the spread as to the relative size of the defects. Grinding into certain defects, or sectioning and viewing under black light will rapidly build up experience and knowledge of the character of defects lying below various types of indications. For best results, inspection should be done in a darkened area. The darker the area of inspection, the more brilliant the indications will show. This is extremely important when looking for very fine indications. The inspection table should be kept free of random fluorescent materials. If penetrant has been spilled in the inspection area, on the table, or the operator's hands, it will fluoresce brilliantly and may confuse the operator.

Visible dye penetrant indications appear as red lines. As the developer dries to a smooth white coating, red indications will appear at the location of defects. If no red indications appear, there are no surface flaws present. No special lighting is required for the visible dye penetrant inspection.

It is possible to examine an indication of discontinuity and to determine its cause as well as its extent. Such an appraisal can be made if something is known about the manufacturing processes to which the part has been subjected. The extent of the indication, or accumulation of penetrant, will show the extent of the discontinuity, and the brilliance will be a measure of its depth. Deep cracks will hold more penetrant and therefore will be broader and more brilliant. Very fine openings can hold only small amounts of penetrant and therefore will appear as fine lines.

The most effective training tool for identifying and recognizing defects is a collection of parts with typical defects which can be referred to frequently. Parts that have been rejected because of defects should be clearly marked or partially damaged so that they will not be confused with acceptable parts. Unless the defects are extremely large the indications will remain on the parts for several months or longer.

It is not advisable to reinspect any part using a different type process than the one originally used. Fluorescent penetrants and visible dye penetrants are not very compatible; therefore, if at all possible, if reinspection of a part is required, the original process should be employed.

Documentation of penetrant inspections can be done on Support Action Forms (SAF's), Maintenance Action Forms (MAF's), or Technical Directive Compliance Forms (TDCF's), depending upon the circumstances which warrant or require the inspection. Figure 3-3 illustrates the use of a MAF for penetrant inspection during a calendar inspection, and figure 3-4 illustrates the TDCF being used because of an Aircraft Bulletin. When the MAF is used, the worker in most cases initiates and completes the form, while the TDCF is usually initiated by Maintenance/Production Control, and the worker complies with it and completes the form.

Detailed information on MAF's and TDCF's and their uses is covered in Military Requirements for Petty Officer 3 & 2, NavPers 10056-C, and OpNav 4790.2 (Series) Instruction.

NONMETALLIC MATERIALS

TRANSPARENT PLASTICS

Transparent plastic materials used in aircraft canopies, windshields, and other transparent enclosures may be divided into two major classes, or groups, depending on their reaction to heat. They are the THERMOPLASTIC materials and the THERMOSETTING materials.

Thermoplastic materials will soften when heated and harden when cooled. These materials can be heated until soft, formed into the desired shape, and when cooled will retain this shape. The same piece of plastic can be reheated and reshaped any number of times without changing the chemical composition of the material.

Thermosetting plastics harden upon heating, and reheating has no softening effect. They cannot be reshaped after once being fully cured by the application of heat. These materials are rapidly being phased out in favor of stretched acrylic, a thermoplastic material.

Transparent plastics are manufactured in two forms of material–solid (monolithic) and laminated. Laminated plastic consists of two sheets of solid plastic bonded to a rubbery inner-layer material similar to the sandwich material used in plate glass.

Laminated transparent plastics are well suited to pressurized applications in aircraft because of their shatter resistance, which is much higher than that of the airstretched solid plastics.

Stretched acrylic is a thermoplastic conforming to Military Specification MIL-P-25690. This specification covers transparent, solid, modified acrylic sheet material having superior crack propagation resistance (shatter resistance, craze resistance, fatigue resistance) as a result of proper hot stretching.

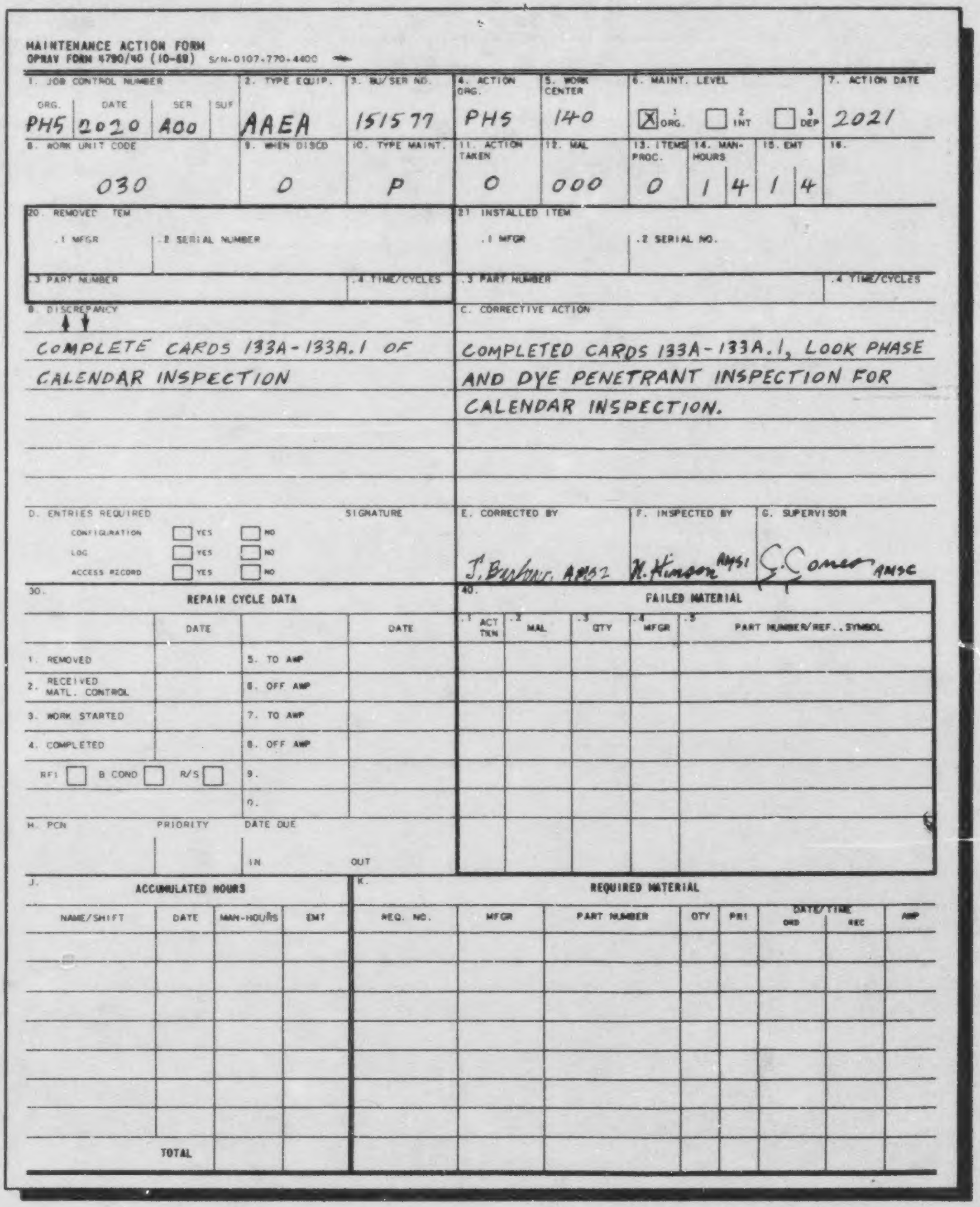
Stretched acrylic is prepared from modified acrylic sheets, using a processing technique in which the sheet is heated to its forming temperature and then mechanically stretched so as to increase its area approximately 3 or 4 times with a resultant decrease in its thickness. Most of the Navy's high-speed aircraft are equipped with canopies made from stretched acrylic plastic.

Identification

Most transparent plastic sheet used in naval aircraft is manufactured in accordance with various MIL specifications, some of which are listed in table 3-6. Individual sheets are covered with a heavy masking paper on which the specification number appears. In addition to serving as a means of identification, the masking paper helps to prevent accidental scratching of the plastic during storage and handling.

Table 3-6.—Transparent plastics.

Type	Specification No.
Solid Thermoplastic	
Thermoplastic	
Heat-resistant acrylic	**MIL-P-5425**
Modified acrylic	**MIL-P-8184**
Stretched modified acrylic (8184)	**MIL-P-25690**
Thermosetting	
Polyester craze resistant	**MIL-P-8257**
Laminated	
Laminated modified acrylic (8184)	**MIL-P-25374**



MAINTENANCE ACTION FORM
OPNAV FORM 4790/40 (10-68) S/N-0107-770-4400

1. JOB CONTROL NUMBER ORG. PH5 / DATE 2020 / SER A00 / SUF	2. TYPE EQUIP. AAEA	3. BU/SER NO. 151577	4. ACTION ORG. PH5	5. WORK CENTER 140	6. MAINT. LEVEL ☒ 1 ORG. ☐ 2 INT ☐ 3 DEP	7. ACTION DATE 2021
8. WORK UNIT CODE 030	9. WHEN DISCD 0	10. TYPE MAINT. P	11. ACTION TAKEN 0	12. MAL 000	13. ITEMS PROC. 0 / 14. MAN-HOURS 1 4 / 15. EMT 1 4	16.

20. REMOVED ITEM .1 MFGR	.2 SERIAL NUMBER	21. INSTALLED ITEM .1 MFGR	.2 SERIAL NO.
.3 PART NUMBER	.4 TIME/CYCLES	.3 PART NUMBER	.4 TIME/CYCLES

B. DISCREPANCY

COMPLETE CARDS 133A-133A.1 OF CALENDAR INSPECTION

C. CORRECTIVE ACTION

COMPLETED CARDS 133A-133A.1, LOOK PHASE AND DYE PENETRANT INSPECTION FOR CALENDAR INSPECTION.

D. ENTRIES REQUIRED SIGNATURE
CONFIGURATION ☐ YES ☐ NO
LOG ☐ YES ☐ NO
ACCESS RECORD ☐ YES ☐ NO

E. CORRECTED BY J. Barbour AMS2
F. INSPECTED BY H. Hinson AMS1
G. SUPERVISOR G. Comer AMSC

30. REPAIR CYCLE DATA

	DATE		DATE
1. REMOVED		5. TO AWP	
2. RECEIVED MATL. CONTROL		6. OFF AWP	
3. WORK STARTED		7. TO AWP	
4. COMPLETED		8. OFF AWP	
RFI ☐ B COND ☐ R/S ☐		9.	
		0.	

H. PCN PRIORITY DATE DUE IN OUT

40. FAILED MATERIAL

.1 ACT TKN	.2 MAL	.3 QTY	.4 MFGR	.5 PART NUMBER/REF..SYMBOL

J. ACCUMULATED HOURS

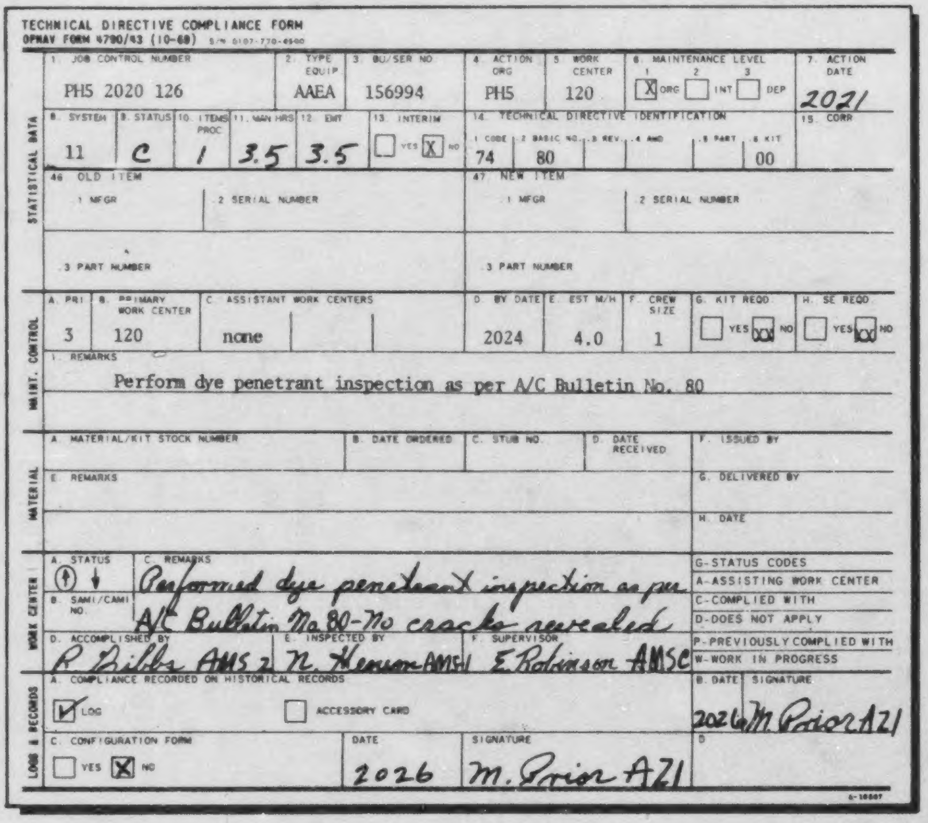
NAME/SHIFT	DATE	MAN-HOURS	EMT
TOTAL			

K. REQUIRED MATERIAL

REQ. NO.	MFGR	PART NUMBER	QTY	PRI	DATE/TIME ORD	DATE/TIME REC	AWP

AM.5

Figure 3-3.—MAF used for penetrant inspection during calendar inspection.



TECHNICAL DIRECTIVE COMPLIANCE FORM
OPNAV FORM 4790/43 (10-69) S/N 0107-770-4500

STATISTICAL DATA
1. JOB CONTROL NUMBER: PH5 2020 126
2. TYPE EQUIP: AAEA
3. BU/SER NO: 156994
4. ACTION ORG: PH5
5. WORK CENTER: 120
6. MAINTENANCE LEVEL: 1 ☒ ORG 2 ☐ INT 3 ☐ DEP
7. ACTION DATE: 2021
8. SYSTEM: 11
9. STATUS: C
10. ITEMS PROC: 1
11. MAN HRS: 3.5
12. EMT: 3.5
13. INTERIM: ☐ YES ☒ NO
14. TECHNICAL DIRECTIVE IDENTIFICATION: .1 CODE 74 .2 BASIC NO. 80 .3 REV. .4 AMD .5 PART .6 KIT 00
15. CORR
46. OLD ITEM: .1 MFGR .2 SERIAL NUMBER .3 PART NUMBER
47. NEW ITEM: .1 MFGR .2 SERIAL NUMBER .3 PART NUMBER

MAINT. CONTROL
A. PRI: 3
B. PRIMARY WORK CENTER: 120
C. ASSISTANT WORK CENTERS: none
D. BY DATE: 2024
E. EST M/H: 4.0
F. CREW SIZE: 1
G. KIT REQD: ☐ YES ☒ NO
H. SE REQD: ☐ YES ☒ NO
I. REMARKS: Perform dye penetrant inspection as per A/C Bulletin No. 80

MATERIAL
A. MATERIAL/KIT STOCK NUMBER
B. DATE ORDERED
C. STUB NO.
D. DATE RECEIVED
E. REMARKS
F. ISSUED BY
G. DELIVERED BY
H. DATE

WORK CENTER
A. STATUS: [✓ ↑] ↓
B. SAMI/CAMI NO.
C. REMARKS: Performed dye penetrant inspection as per A/C Bulletin No. 80 - No cracks revealed
D. ACCOMPLISHED BY: R. Bibbs AMS 2
E. INSPECTED BY: N. Henson AMS 1
F. SUPERVISOR: E. Robinson AMSC

G-STATUS CODES
A-ASSISTING WORK CENTER
C-COMPLIED WITH
D-DOES NOT APPLY
P-PREVIOUSLY COMPLIED WITH
W-WORK IN PROGRESS

LOGS & RECORDS
A. COMPLIANCE RECORDED ON HISTORICAL RECORDS: ☑ LOG ☐ ACCESSORY CARD
B. DATE: 2026 SIGNATURE: M. Prior AZ1
C. CONFIGURATION FORM: ☐ YES ☒ NO
DATE: 2026 SIGNATURE: M. Prior AZ1
D

6-10807

AM.7

Figure 3-4.—TDCF documentation for penetrant inspection.

Identification of unmasked sheets of plastic is often difficult; however, the following information may serve as an aid. MIL-P-8184, a modified acrylic plastic, has a slight yellowish tint when viewed from the edge; MIL-P-8257, a thermosetting polyester plastic, has a bluish or blue-green tint; and MIL-P-5425, heat-resistant acrylic, is practically clear. In addition, stretched acrylic sheets and fabricated assemblies are permanently marked to insure positive identification.

Plastic enclosures on aircraft may be distinguished from plate glass enclosures by tapping lightly with a blunt instrument. Plastic will resound with a dull thud or soft sound, whereas plate glass will resound with a metallic sound or ring.

Storage and Handling

Transparent plastic sheets are available in a number of thicknesses and sizes which can be cut and formed to required size and shape. These plastics will soften and/or deform when heated sufficiently; therefore, storage areas having high temperatures must be avoided. Plastic sheets should be kept away from heating coils, radiators, hot water, and steam lines. Storage should be in a cool, dry location away from solvent fumes, such as may exist near paint spray and paint storage areas. Paper masked transparent plastic sheets should be kept indoors as direct rays of the sun will accelerate deterioration of the masking paper adhesive, causing it to cling to the plastic so that removal is difficult.

Plastic sheets should be stored with the masking paper in place, in bins which are tilted at approximately 10 degrees from the vertical to prevent buckling. If it is necessary to store sheets horizontally, care should be taken to avoid chips and dirt getting between the sheets. Stacks should not be over 18 inches high, and small sheets should be stacked on the larger ones to avoid unsupported overhang. Storage of transparent plastic sheets presents no special fire hazard, as they are slow burning.

Masking paper should be left on the plastic sheet as long as possible. Care should be exercised to avoid scratches and gouges which may be caused by sliding sheets against one another or across rough or dirty tables.

Formed sections should be stored so that they are amply supported and there is no tendency for them to lose their shape. Vertical nesting should be avoided. Protect formed parts from temperatures higher than 120°F. Protection from scratches may be provided by applying a protective coating.

If masking paper adhesive deteriorates through long or improper storage, making removal of paper difficult, moisten the paper with aliphatic naphtha, which will loosen the adhesive. Sheets so treated should be washed immediately with clear water.

CAUTION: Aliphatic naphtha is highly volatile and flammable. Extreme care should be exercised when using this solvent.

Do not use gasoline, alcohol, kerosene, xylene, ketones, lacquer thinners, aromatic hydrocarbons, ethers, glass cleaning compounds, or other unapproved solvents on transparent acrylic plastics to remove masking paper or other foreign material, as these will soften and/or craze the plastic surface. (NOTE: Just as woods split and metals crack in areas of high, localized stress, plastic materials develop, under similar conditions, small surface fissures called CRAZING. These tiny cracks are approximately perpendicular to the surface, very narrow in width, and usually not over 0.01 inch in depth. These tiny fissures are not only an optical defect, but also a mechanical defect, inasmuch as there is a separation or parting of the material. Once a part has been crazed, neither the optical nor mechanical defect can be removed permanently; therefore, prevention of crazing is a necessity.)

When it is necessary to remove masking paper from the plastic sheet during fabrication, the surface should be remasked as soon as possible. Either replace the original paper on relatively flat parts or apply a protective coating on curved parts.

REINFORCED PLASTICS

Glass fiber reinforced plastic and honeycomb are used in the construction of radomes, wingtips, stabilizer tips, antenna covers, fairings, access covers, etc. It has excellent dielectric characteristics, making it ideal for use in radomes. Its high strength/weight ratio, resistance to mildew and rot, and ease of fabrication make it equally suited for other parts of the aircraft.

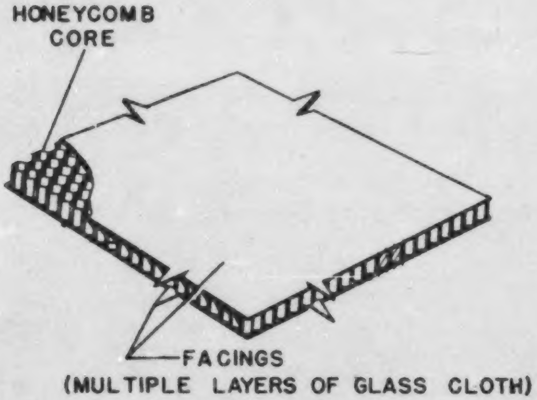
The manufacture of reinforced plastic laminates involves the use of liquid resins reinforced with a filler material. The resin, when properly treated with certain agents known as catalysts, or hardeners, changes to an infusible solid.

The reinforcement materials are impregnated with the resin while the latter is still in the liquid (uncured) state. Layers or plies of cloth are stacked up and heated under pressure in a mold to produce the finished, cured shape. Another technique, called "filament winding," consists of winding a continuous glass filament or tape, impregnated with uncured resin, over a rotating male form. Cure is accomplished in a manner similar to the woven cloth reinforced laminates.

Glass fiber reinforced honeycomb consists of a relatively thick, central layer called the core and two outer laminates called facings. (See figure 3-5.)

The core material commonly used in radome construction consists of a honeycomb structure made of glass cloth impregnated either with a polyester or epoxy, or a combination of nylon and phenolic resin. The material is normally fabricated in blocks that are later cut on a bandsaw to slices of the exact thickness desired, or it may be originally fabricated to the proper thickness.

The facings are made up of several layers of glass cloth, impregnated and bonded together



AM.230

Figure 3-5.—Reinforced plastic.

with resin. Each layer of cloth is placed in position and impregnated with resin before another layer is added. Thicker cloths are normally used for the body of the facings, with one or more layers of a finer weave cloth on the surface.

The resins are thick, sirupy liquids of the so-called contact-pressure type (requiring little or no pressure during cure), some times referred to as contact resins. They are usually thermosetting polyester or epoxy resins. Cure can be effected by adding a catalyst and heating, or they can be cured at different temperatures by adjusting the amount and type of catalysts. Inspection and repair procedures for reinforced plastic are covered in chapter 7 of this manual.

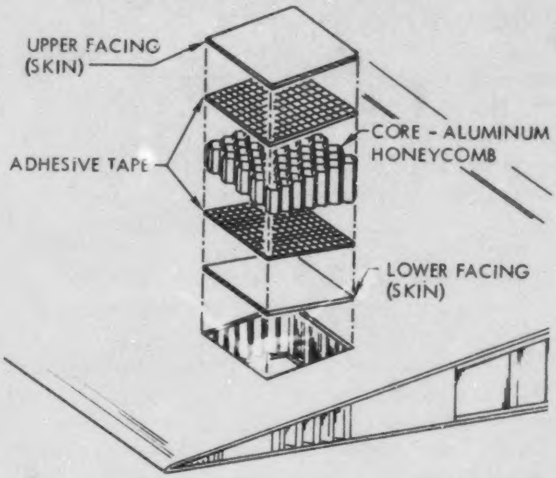
SANDWICH CONSTRUCTION

From the standpoint of function, sandwich parts in naval aircraft can be divided into two broad classes: (1) radomes and (2) structural. The first class, radomes, is a reinforced plastic sandwich construction designed primarily to permit accurate and dependable functioning of the radar equipment. This type construction was discussed in the preceding section under reinforced plastics.

The second class, referred to as structural sandwich, normally has either metal or reinforced plastic facings on cores of aluminum or balsa wood. This material is found in a variety of places such as wing surfaces, decks, bulkheads, stabilizer surfaces, ailerons, trim tabs, access doors, and bomb bay doors. Figure 3-6 illustrates one type of sandwich construction using a honeycomb-like aluminum alloy core, sandwiched between aluminum alloy sheets, called facings. The facings are bonded to the lightweight aluminum core with a suitable adhesive so as to develop a strength far greater than that of the components themselves when used alone.

Another type structural sandwich construction consists of a low-density balsa wood core combined with high-strength aluminum alloy facings bonded to each side of the core. The grain in the balsa core runs perpendicular to the aluminum alloy facings, and the core and aluminum facings are firmly bonded together under controlled temperatures and pressures.

The facings in this type construction carry the major bending loads, and the cores serve to support the facings and carry the shear loads. The outstanding characteristics of sandwich construction are strength, rigidity, lightness, and surface smoothness.



AM.231

Figure 3-6.—Sandwich construction.

CHAPTER 4

AIRFRAME CONSTRUCTION

Familiarity with the various terms used in reference to airframe construction is one of the first requirements of the Aviation Structural Mechanic. Maintenance of the airframe is primarily the responsibility of the AMS; therefore, he should be familiar with the principal units which make up the airframe and know the purpose, location, and construction features of each.

The airframe of a fixed-wing (sometimes referred to as "conventional" when distinguishing from helicopters) aircraft is generally considered to consist of five principal units—the fuselage, wings, stabilizers, flight control surfaces, and landing gear. Helicopter airframes consist of the fuselage (or hull), main rotor and related gearbox, tail rotor (on helicopters with a single main rotor), and the landing gear. A further breakdown of these principal units into major components is made in this chapter, describing the purpose, location, and construction features of each.

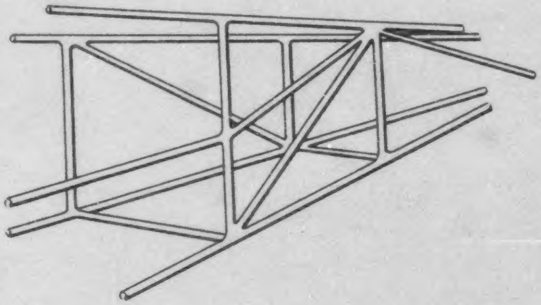
FIXED-WING AIRCRAFT

FUSELAGE

The fuselage is the main structure or body of the airframe. It provides space for personnel, cargo, controls, and most of the accessories and other equipment. In single-engine aircraft, it also houses the powerplant. In multiengine aircraft the engines may either be in the fuselage, or attached to or suspended from the wing structure.

Fuselages of the various types of naval aircraft have much in common from the standpoint of outline and general design. They vary mainly in size and arrangement of the different compartments. Detail design varies with the manufacturer and the requirements of the type of service which they are intended to perform. For instance, the U-16 (widely used in Search and Rescue) may have to operate as an amphibious aircraft. When operating from water the fuselage, being watertight, keeps the aircraft afloat. In fact, the fuselage so nearly performs the function of a boat that it is called the HULL.

Two general types of fuselage construction are the WELDED STEEL TRUSS and the MONOCOQUE designs. The welded steel truss is used in many of the smaller, civilian type aircraft and was formerly used in many Navy aircraft. It is still being used in some helicopters. An example of truss type construction is shown in figure 4-1.



AM.232

Figure 4-1.—Truss type fuselage construction.

The monocoque design relies largely on the strength of the skin or covering to carry the various loads (discussed in chapter 3). This design may be divided into three classes: MONOCOQUE, SEMIMONOCOQUE, and REINFORCED SHELL. The monocoque has as its only reinforcement vertical rings, station webs, formers, and bulkheads. The semimonocoque has, in addition to these vertical reinforcements, the skin reinforced by longitudinal members. The reinforced shell has the skin reinforced by a complete framework of structural members. Different portions of the same fuselage may belong to any one of these three classes, but most Navy aircraft are considered to be of semimonocoque type construction.

The semimonocoque fuselage is constructed primarily of the alloys of aluminum and magnesium, although steel and titanium are found in areas of high temperatures. Primary bending loads are taken by the LONGERONS, which usually extend across several points of support. The longerons are supplemented by other longitudinal members, called STRINGERS. Stringers are more numerous and lighter in weight than are longerons. The vertical structural members are referred to as BULKHEADS, FRAMES, and FORMERS. The heaviest of these vertical members are located at intervals to carry concentrated loads and at points where fittings are used to attach other units, such as the wings, powerplant, and stabilizers. Figure 4-2 shows a modified form of the monocoque design now used in all combat-type aircraft.

The metal skin, or covering, is riveted to the longerons, bulkheads, and other structural members and carries part of the load. Skin thickness varies with the loads carried and the stresses sustained.

There are a number of advantages in the use of the semimonocoque fuselage. The bulkheads,

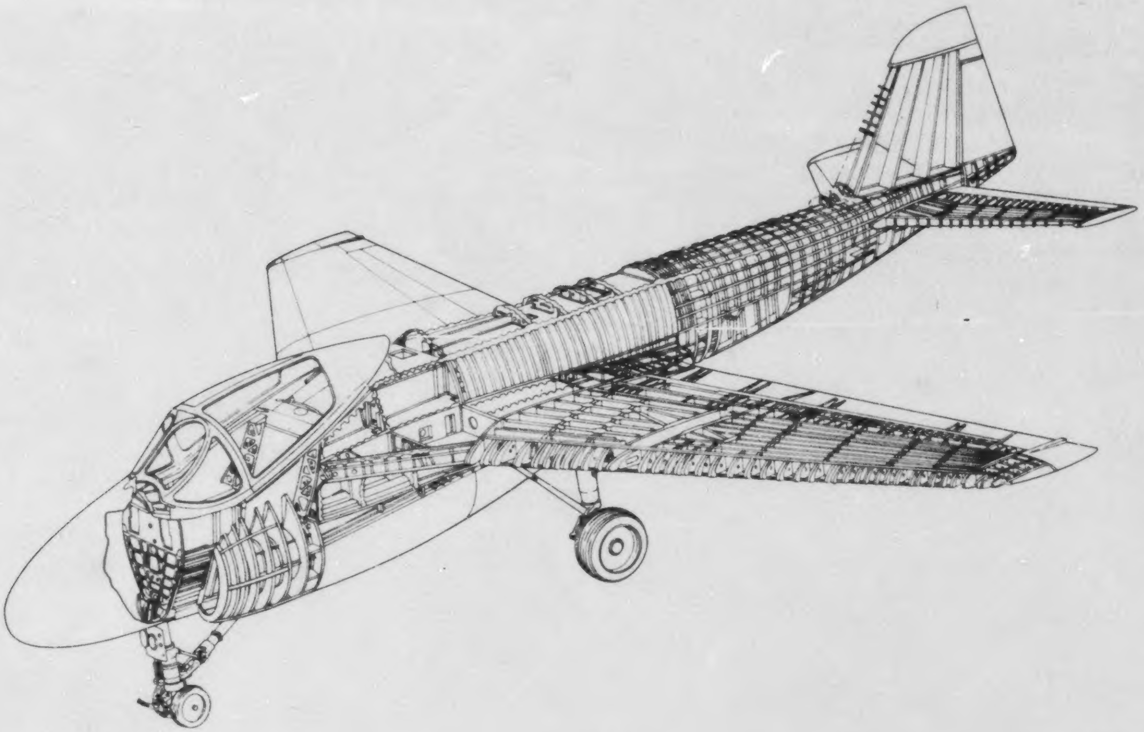

AM.233

Figure 4-2.—Semimonocoque fuselage construction.

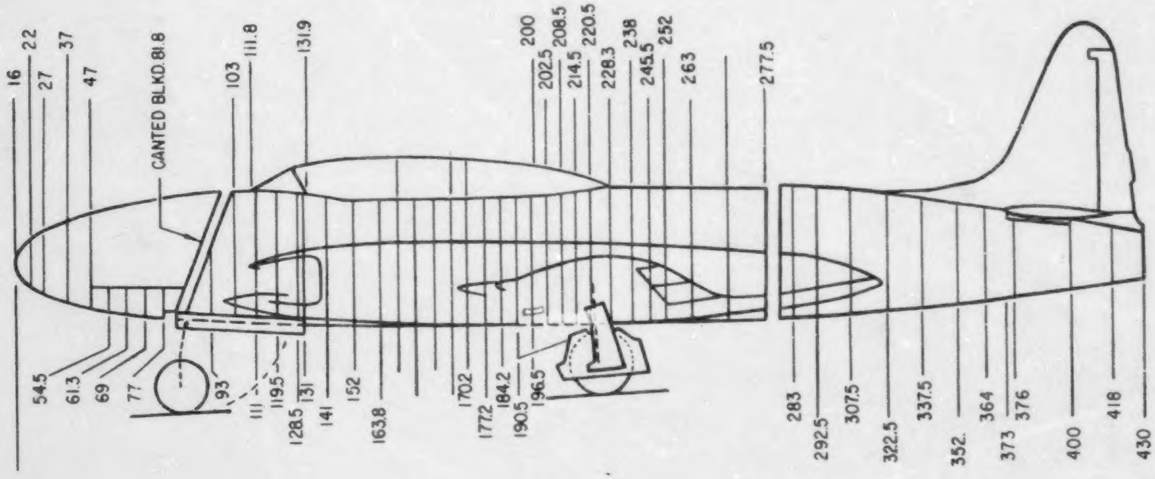
frames, stringers, and longerons facilitate the design and construction of a streamlined fuselage, and add to the strength and rigidity of the structure. The main advantage; however, lies in the fact that it does not depend on a few members for strength and rigidity. This means that a semimonocoque fuselage, because of its stressed-skin construction, may withstand considerable damage and still be strong enough to hold together.

Fuselages are generally constructed in two or more sections. On fighters and other small types of aircraft, they are generally made in two or three sections, while larger aircraft may be made up of as many as six sections.

Various points on the fuselage are located by station number. Station 0 (zero) is usually located at or near the nose of the aircraft, and other stations are located at measured distances (in inches) aft of station zero.

A typical station diagram is shown in figure 4-3. On this particular aircraft, station 0 is located 16 inches forward of the nose. The fuselage break (for engine removal) is located at station 277.5.

Quick access to the accessories and other equipment carried in the fuselage is provided for by numerous access doors, inspection plates, landing wheel wells, and other openings. Servicing diagrams showing the arrangement of equipment and location of access doors are supplied by the manufacturer in the Maintenance Instructions Manual and Maintenance Requirements Cards for each aircraft. Figure 4-4 shows the servicing diagram for a typical aircraft.



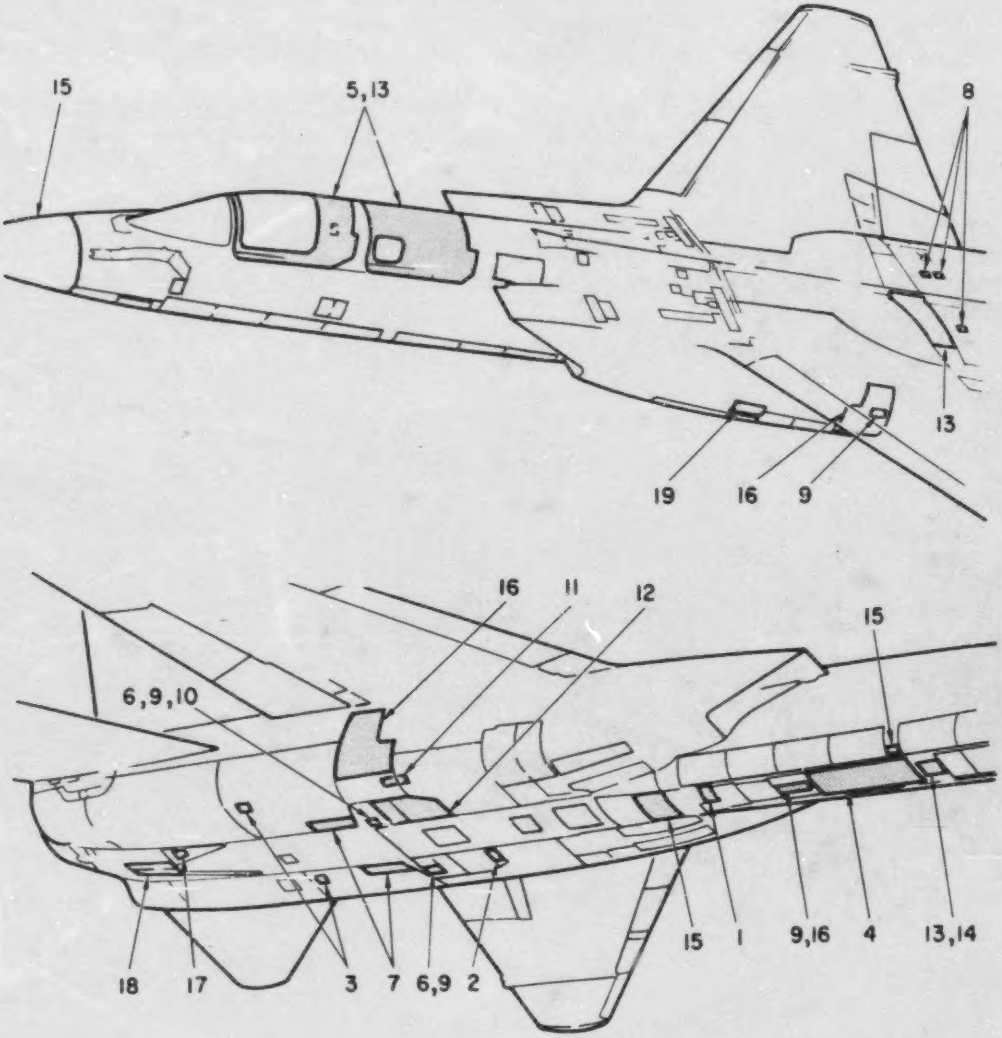
AM.234

Figure 4-3.—Typical station diagram.

WINGS

The wings are airfoils designed to develop the major portion of the lift of the aircraft. The particular design for any given aircraft depends upon a number of factors; for example, size, weight, and use of the aircraft, its desired landing speed and desired rate of climb. The wings are designated as left and right, corresponding to the left and right sides of the pilot when seated in the aircraft.

The wings of Navy aircraft are usually of all-metal construction with cantilever design; that is no external bracing. Both aluminum alloy and magnesium alloy are used extensively in wing construction. The internal structure is



AM.235

1. Forward refueling and defueling receptacle.
2. Aft refueling and defueling receptacle.
3. Oil filling and draining.
4. Liquid oxygen filling and draining.
5. Emergency oxygen servicing.
6. Hydraulic reservoir servicing panel.
7. Hydraulic systems servicing.
8. Hydraulic reservoir air dump valves and sight gages.
9. Accumulator servicing.
10. Pneumatic system servicing.
11. Compressor oil reservoir.
12. Pneumatic system chemical dryer.
13. Pneumatic system depressurizing and draining.
14. Electronic pressurizing desiccator.
15. Pitot-static system draining.
16. Landing gear strut servicing.
17. Arresting gear snubber.
18. Arresting gear hook bumper.
19. A-c external power.

Figure 4-4.—Typical servicing diagram.

made up of SPARS and STRINGERS running spanwise, and RIBS and FORMERS running chordwise (leading edge to trailing edge). The spars are the principal structural members of the wing and are often referred to as BEAMS.

One of the numerous methods of wing construction is shown in figure 4-5. In this illustration two main spars are used with ribs placed at intervals to space them and develop wing contour. This is called TWO-SPAR construction. Other variations of wing construction include MONOSPAR (one spar), MULTI-SPAR (three or more spars), and BOX BEAM in which stringers and spar-like sections are joined together in a box shaped beam about which the remainder of the wing is constructed.

The skin is riveted, or in some cases attached with screws, to all these internal members and carries part of the wing stresses. During flight, applied loads which are imposed on the wing structure act primarily on the skin. From the skin they are transmitted to the ribs and from the ribs to the spars. The spars support all distributed loads as well as concentrated weights, such as fuselage, landing gear, and (on multiengine aircraft) nacelles. Corrugated sheet aluminum alloy is sometimes used as a subcovering for wing structures, especially on very large aircraft. The C-121 wing has this type of construction.

The wing, like the fuselage, is constructed in sections. One commonly used type is made up of a CENTER SECTION with OUTER PANELS and WINGTIPS. Another arrangement may have WINGSTUBS as integral parts of the fuselage in place of the center section, although from the outside they are very much like the wing center section in appearance.

Inspection openings and access doors are provided, usually on the lower surfaces of the wing, and drain holes are placed in the lower surfaces. On some aircraft, built-in walkways are provided on the areas where it is intended that personnel will walk or step. On others there are

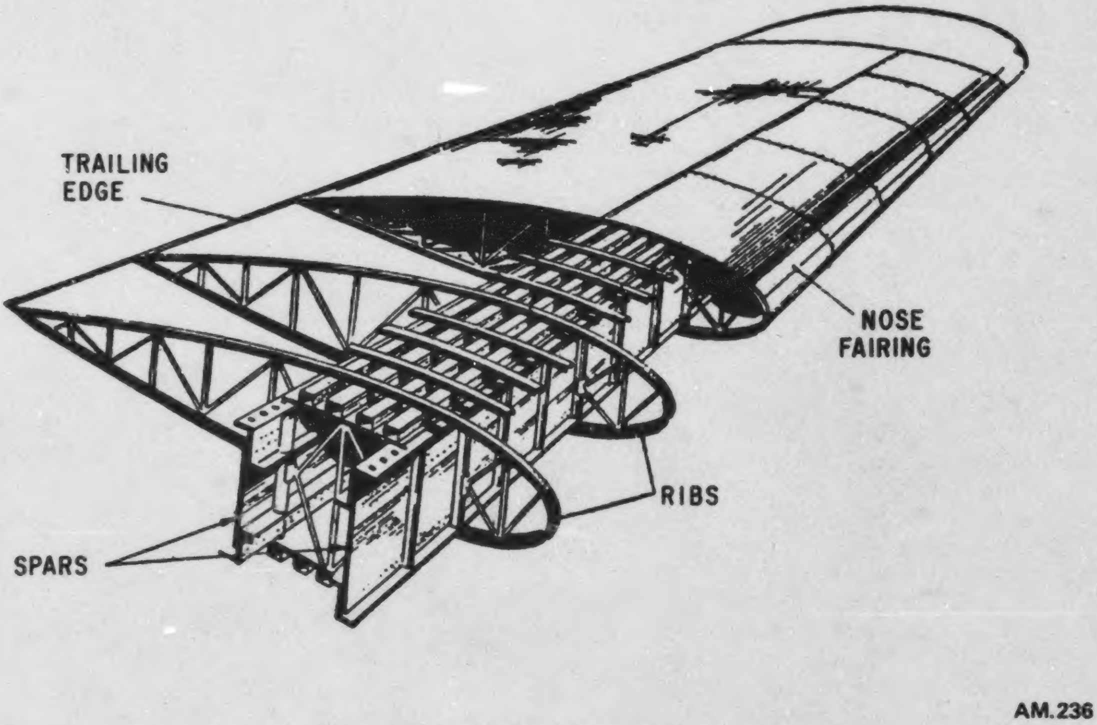
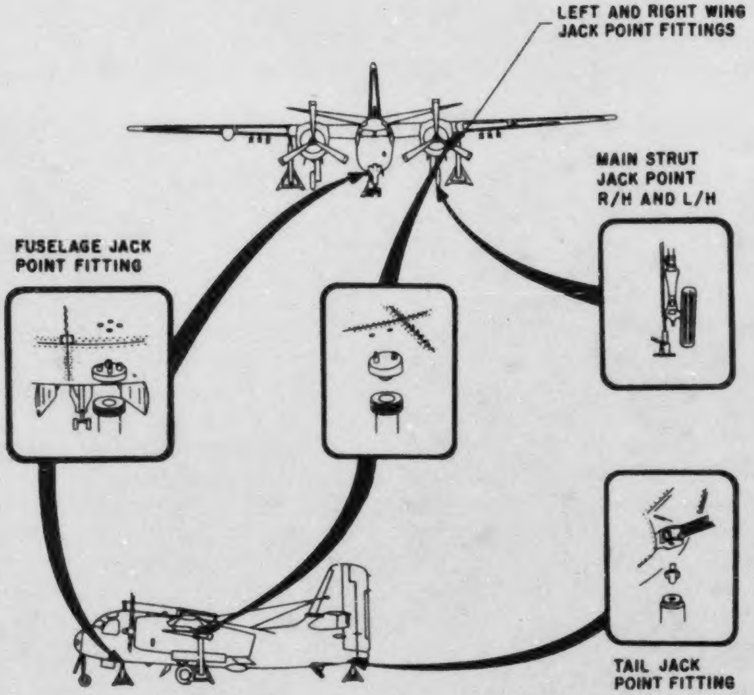


Figure 4-5.—Two-spar wing construction.


LEFT AND RIGHT WING JACK POINT FITTINGS
MAIN STRUT JACK POINT R/H AND L/H
FUSELAGE JACK POINT FITTING
TAIL JACK POINT FITTING

AM.237

Figure 4-6.—Typical jacking diagram.

no built-in walkways, but removable mats or covers are used to protect the wing surface when servicing the aircraft.

Jacking points are provided on the underside of each wing in the form of recessed openings for quick installation of jackpads. A typical jacking diagram is shown in figure 4-6. On some aircraft the jackpads may be used as tiedown fittings for tiedown of the aircraft; other aircraft make use of removable jackpads and more convenient tiedown fittings. Jacking and tiedown procedures are described fully in chapter 12.

Various points on the wing are located by station number. Wing station 0 (zero) is located at the centerline of the fuselage, and all wing stations are measured outboard from that point, in inches.

STABILIZERS

The stabilizing surfaces of an aircraft consist of vertical and horizontal airfoils, called the VERTICAL STABILIZER (or fin) and the HORIZONTAL STABILIZER. These two airfoils, together with the rudder and elevators, form the tail section. For inspection and maintenance purposes the entire tail section is considered a single unit of the airframe called the EMPENNAGE.

The primary purpose of the stabilizers is to stabilize the aircraft in flight, that is, to keep the craft in straight and level flight. The vertical stabilizer maintains the stability of the aircraft about its vertical axis. This is known as DIRECTIONAL STABILITY. The vertical stabilizer usually serves as the base to which the rudder is attached. The horizontal stabilizer provides stability of the aircraft about the lateral axis. This is LONGITUDINAL STABILITY. It usually serves as the base to which the elevators are attached.

On all high-performance aircraft the horizontal stabilizer is a movable airfoil, controllable from the cockpit, commonly referred to as the "flying tail." At extremely high (at or about the speed of sound) speeds, the elevators have a tendency to lose their effectiveness. Forces acting upon the control stick become very high, and longitudinal control of the aircraft becomes difficult. By changing the angle of attack of the stabilizer, adequate longitudinal control is maintained. This is accomplished by raising or lowering the leading edge of the stabilizer.

Construction features of the stabilizers are in many respects identical with those of the wings. They are usually of all-metal construction and of cantilever design. Monospar and two spar construction are both commonly used. Ribs develop the cross-sectional shape. Fairing is used to round out the angles formed between these surfaces and the fuselage.

FLIGHT CONTROL SURFACES

The flight control surfaces are hinged or movable airfoils designed to change the attitude of the aircraft during flight. The basic controls are the AILERONS, ELEVATORS, and RUDDER. A miscellaneous grouping of the remainder of the flight controls would include the TRIM TABS, SPRING TABS, WING FLAPS, SPEED BRAKES, SLATS, and SPOILERS.

Basic Controls

The basic controls–ailerons, elevators, and rudder–are used to move the aircraft about its three axes. (See fig. 4-7.) The ailerons are attached to the trailing edge of the wings and control the rolling (or banking) motion of the aircraft. This is known as LONGITUDINAL CONTROL since the roll is about the longitudinal axis. The elevators, attached to the horizontal stabilizers, control the climb or descent (pitching motion of the aircraft). This is known as LATERAL CONTROL since the movement is about the lateral axis. The rudder, attached to the vertical stabilizer, determines the horizontal direction of flight (turning or yawing motion) of the aircraft. This is DIRECTIONAL CONTROL and it occurs about the vertical axis of the aircraft.

The ailerons and elevators are operated from the cockpit by a control stick on fighter type aircraft and by a wheel and yoke assembly on large aircraft such as transports and patrol planes. The rudder is operated by rudder pedals on all types of aircraft.

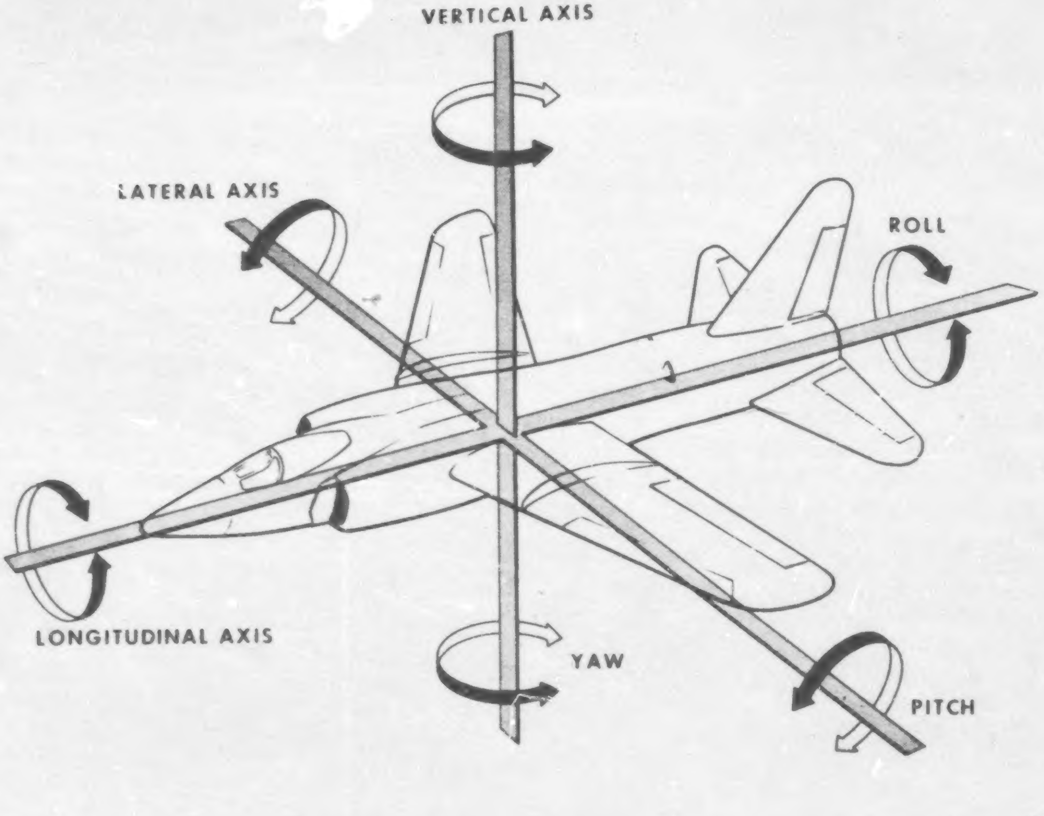
The ailerons are operated by a lateral (side to side) movement of the control stick, or a turning motion of the wheel on the yoke, and are interconnected in the control system so that they work simultaneously in opposite directions to one another. As one aileron moves downward to increase lift on its side of the fuselage, the aileron on the opposite side of the fuselage moves upward to decrease lift on its side. This opposing action results in more lift being produced by the wing on one side of the fuselage than on the other side, the result being a controlled movement or roll due to unequal forces on the wings.

The elevators are operated by a fore-and-aft movement of the control stick or yoke, as the case may be. Raising the elevators causes the aircraft to climb; lowering the elevators causes it to dive or descend. The elevators are raised by pulling back on the stick or yoke, and they are lowered by pushing the stick or yoke forward.

The rudder is operated by the rudder pedals and is used to move the aircraft about the vertical axis. Moving the rudder to the right turns the aircraft to the right; moving it to the left turns the aircraft to the left. The rudder is moved to the right by pushing the right rudder pedal, and is moved to the left by pushing the left pedal.

Practically all high-speed aircraft have hydraulic actuators incorporated within the flight control systems to aid the pilot in movement of the control surfaces at accelerated airspeeds. Another method of decreasing the amount of force required to operate the controls is by the use of spring tabs, which are described later.

The construction of control surfaces is similar to that of the wing and stabilizers. They are



AM.238

Figure 4-7.—Axes and fundamental movements of the aircraft.

usually built around a single spar or torque tube. Ribs are fitted to the spar near the leading edge, and at the trailing edge are joined together with a suitable metal strip or extrusion. The control surfaces of some aircraft are fabric-covered, but all jet aircraft have all-metal surfaces for additional strength. Some basic control surfaces have lead counterweights inside the leading edge. This balances the surface, making it easier to move the surface in flight. Counterweights also prevent the surface from fluttering during flight.

For greater strength, especially in thinner airfoil sections typical of trailing edges, a honeycomb type of construction is utilized. (This type of material is described in detail in chapter 3.)

Miscellaneous Flight Controls

Miscellaneous flight controls include those controls not designated as basic controls. These controls supplement the basic controls by aiding the pilot in controlling his aircraft. There are various types used on naval aircraft, but only the most common are discussed here.

TRIM TABS.–Trim tabs are small airfoils recessed into the trailing edge of a basic control surface. Their purpose is to enable the pilot to trim out any unbalanced condition which might exist during flight, without exerting any pressure on the control stick or rudder pedals. Each trim tab is hinged to its parent control surface, but is operated independently by a separate control.

Trimming is accomplished by setting the tab in the opposite direction to that in which it is desired for the basic control surface to be moved. The airflow striking the trim tab causes the larger surface to move to a position that will correct the unbalanced condition of the aircraft.

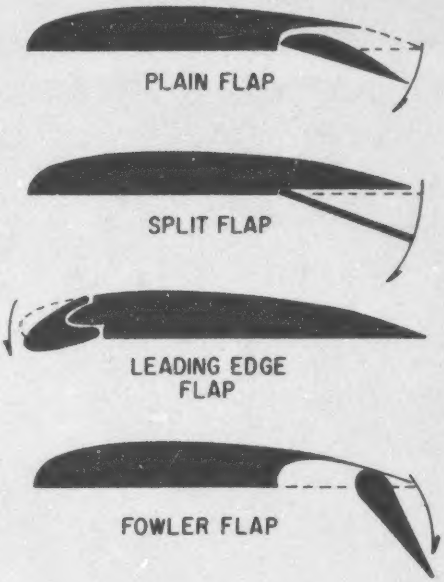
For example, to trim out a hose-heavy condition, the pilot sets the elevator trim tab in the DOWN position. This causes the elevator to be moved and held in the UP position, which in turn causes the tail of the aircraft to be lowered. Without the use of the trim tab, the pilot would have to hold the elevator in the UP position by exerting constant pressure on the control stick or wheel.

Internal construction of trim tabs is similar to that of the other control surfaces, although increasing use is being made of plastic materials to fill the tab completely, thus improving its stiffness. They may also be honeycomb filled. Tabs are covered with either metal or reinforced plastic. Trim tabs are actuated either electrically or manually on all aircraft.

SPRING TABS.–Spring tabs are similar in appearance to trim tabs, but serve an entirely different purpose. Spring tabs are used for the same purpose as hydraulic actuators, that is, to aid the pilot in moving a larger control surface.

On the P-2 aircraft, a spring tab is hinged to the trailing edge of each aileron alongside the trim tab. The spring tab is actuated by a spring-loaded, push-pull rod assembly which is also linked to the aileron control linkage. The linkage is connected in such a way that movement of the aileron in one direction causes the spring tab to be deflected in the opposite direction. This provides a balanced condition, thus reducing the amount of force required by the pilot to move the ailerons. The deflection of the spring tab is directly proportional to the aerodynamic load imposed upon the aileron. Therefore, at low speeds the spring tab remains in a neutral position with respect to the aileron (faired) and the aileron is then entirely manually controlled. At high speeds, however, where the aerodynamic load is great, the tab functions as an aid to the pilot in moving the primary control surface. Spring tabs are referred to by some manufacturers as balance tabs, other may call them servo tabs.

WING FLAPS.–Wing flaps are used to give the aircraft extra lift. Their purpose is to reduce the landing speed, thereby shortening the length of the landing rollout, and to facilitate landing in small or obstructed areas by permitting the gliding angle to be increased without greatly increasing the approach speed. In addition, the use of flaps during takeoff serves to reduce the length of the takeoff run.



AM.239

Figure 4-8.–Types of flaps.

Most flaps are hinged to the lower trailing edges of the wings inboard of the ailerons; however, leading edge flaps are in use on at least one model Navy aircraft, the F-4, Phantom II. Four types of flaps are shown in figure 4-8. The PLAIN type flap forms the trailing edge of the airfoil when the flap is in the up position. In the SPLIT flap, the trailing edge of the airfoil is split and the lower half is so hinged that it can be lowered to form the flap. The FLOWER flap operates on rollers and tracks, causing the lower surface of the wing to roll out and then extend downward. The LEADING EDGE flap operates similar to the plain flap, that is, it is hinged on the bottom side and, when actuated, the leading edge of the wing actually extends in a downward direction to increase the camber of the wing. Leading flaps are used in conjunction with other type flaps.

SPOILERS.–Spoilers, in general, are for the purpose of decreasing wing lift; however, their specific design, function, and use vary with different type aircraft.

The spoilers on the P-2 aircraft are long narrow surfaces, hinged at their leading edge to the upper wing skin. (See fig. 4-9.) In the retracted position, the spoiler is flush with the wing skin. The action of the spoilers is to destroy the smooth flow of air over the wing so that burbling takes place. The lift is consequently greatly reduced and considerable drag is added to the wing. Spoilers are effective for lateral control of the P-2 at high angles of attack. In the extended position, the spoiler is pivoted up and forward approximately 60 degrees above the hinge point.

Another type of spoiler in common use is a long, slender, curved and perforated baffle that is raised edgewise through the wing upper surface forward of the aileron. It also disrupts the orderly flow of air over the airfoil and destroys lift. This type of spoiler is used on S-2 aircraft and is also illustrated in figure 4-9.

The S-2 spoilers are actuated through the same linkage that actuates the ailerons. This arrangement makes movement of the spoiler dependent upon movement of the aileron. The linkage to the aileron is devised so that the spoiler is extended only when the aileron is raised. In other words, when the aileron moves downward, no deflection of the spoiler takes place.

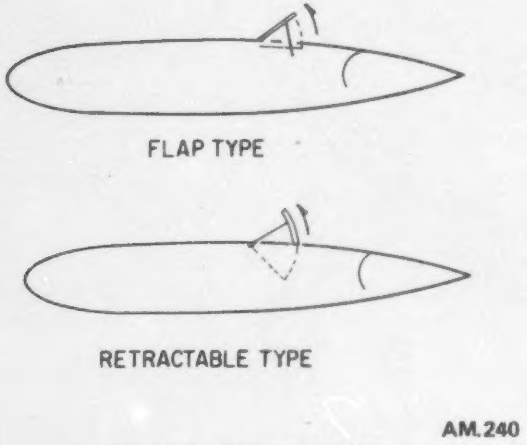


Figure 4-9.—Types of spoilers.

Lateral control of the A-5 is exercised entirely through a system of spoilers and deflectors. In this installation, an automatic ratio changer provides reduced throw of the spoilers and deflectors for the same amount of stick movement when above a given speed. This reduces the rate of roll and keeps it within controllable limits.

SPEED BRAKES.--Speed brakes are hinged movable control surfaces used for reducing the speed of aircraft. Some manufacturers refer to them as DIVE BRAKES, others call them DIVE FLAPS. On some aircraft they are hinged to the sides or bottom of the fuselage, on others they are attached to the wings. Regardless of their location, speed brakes serve the same purpose on all aircraft on which they are used. Their primary purpose is to keep the speed from building up too high in dives. They are also used in slowing down the speed of the aircraft preparatory to landing. Speed brakes are operated hydraulically or electrically.

SLATS.--Slats are movable control surfaces attached to the leading edge of the wing. When the slat is retracted, it forms the leading edge of the wing. When the slat is open (extended forward), a slot is created between the slat and the wing leading edge. Thus, high-energy air is introduced into the boundary layer over the top of the wing. At low airspeeds this improves the lateral control handling characteristics, allowing the aircraft to be controlled at airspeeds below the otherwise normal landing speed. This is known as "boundary layer control." Boundary layer control is intended primarily for use during operations from carriers; that is, for catapult takeoffs and arrested landings.

Boundary layer control can also be accomplished by directing high-pressure engine bleed air through a narrow orifice located just forward of the wing flap leading edge. This latter method is used on the T-1 aircraft. (Review NavPers 10307-C, Airman.)

LANDING GEAR

The landing gear of fixed-wing aircraft consists of main and auxiliary units. For land-based aircraft and amphibians, two main wheels are placed side by side under the wings or under the fuselage, and an auxiliary wheel is located either under the nose or tail. If the aircraft is designed for carrier operations, an arresting gear (hook) is also provided. When amphibians are operating from water, the hull provides buoyancy, but because of the large wingspan, wingtip floats are needed to provide stability at low speeds.

The landing gear of the earliest aircraft consisted merely of protective skids attached to the lower surfaces of the wing and fuselage. As aircraft developed, skids became impractical, and were replaced by a pair of wheels placed side by side ahead of the center of gravity with a tail skid supporting the aft section of the aircraft. The tail skid was later replaced by a swiveling tailwheel. This arrangement was standard on all land-based aircraft for so many years that it became known as the conventional type landing gear. As the speed of aricraft increased, the elimination of drag became increasingly important. This led to the development of retractable landing gear.

Just before World War II, new aircraft were designed with the main landing gear located behind the center of gravity and an auxiliary gear under the nose of the fuselage. This became known as the tricycle type landing gear, and in many ways, it is a big improvement over the conventional type. The tricycle gear is more stable in motion on the ground, maintains the fuselage in a level position which increases the pilot's visibility and control, and also makes landing easier, especially in cross winds. Nearly all present-day Navy aircraft including amphibians are equipped with this type landing gear.

Main Landing Gear

A main landing gear assembly is shown in figure 4-10. The major components of the assembly are shock strut, tire, tube, wheel, retracting and extending mechanism, and side struts and supports. Tires, tubes, and wheels are discussed in chapter 9. A description of the major components follows.

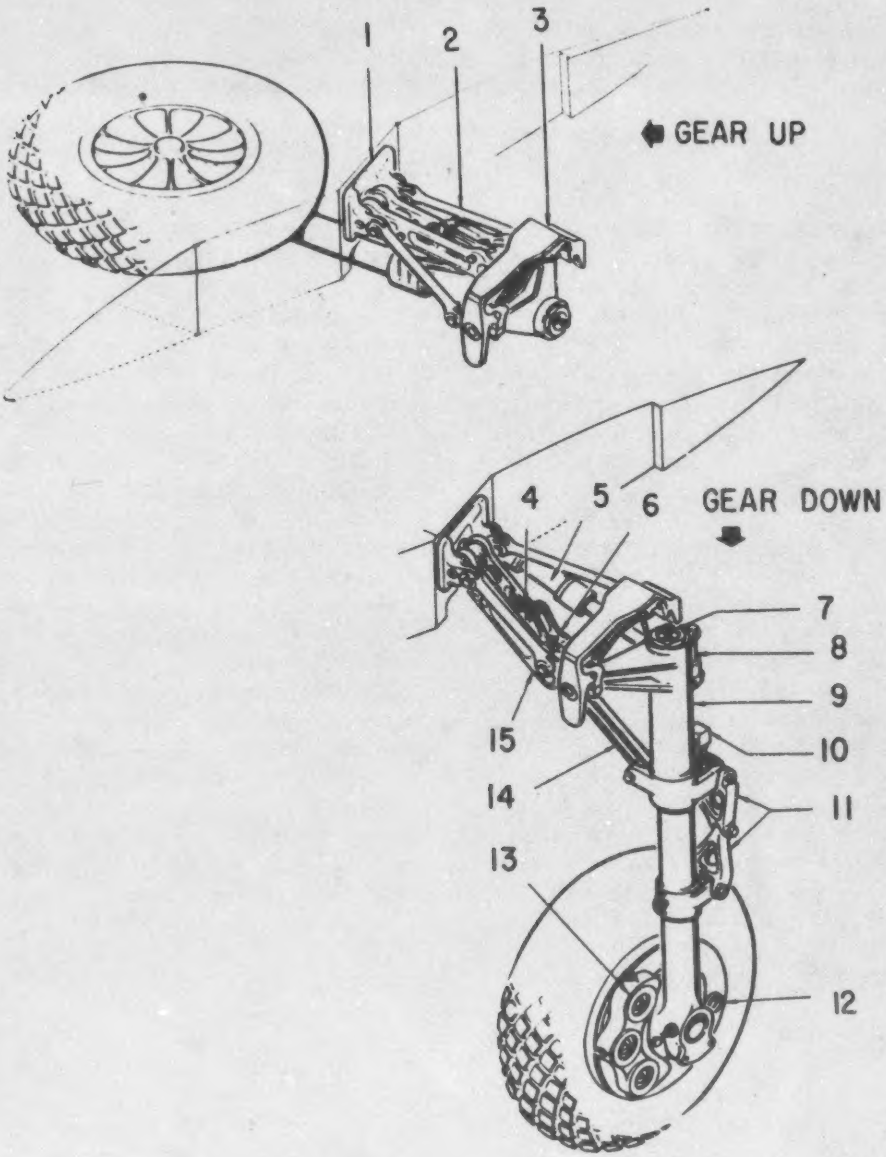
The shock strut absorbs the shock that otherwise would be sustained by the airframe structure during takeoff, taxiing, and landing. The AIR-OIL type shock strut is used on all Navy aircraft. This type strut is composed essentially of two telescoping cylinders filled with hydraulic fluid and compressed air or nitrogen. Figure 4-11 shows the internal construction of a shock strut.

The telescoping cylinders, known as cylinder and piston, when assembled, form an upper and lower chamber for movement of the fluid. The lower chamber (piston) is always filled with fluid, while the upper chamber (cylinder) contains compressed air or nitrogen. An orifice is placed between the two chambers through which fluid passes into the upper chamber during compression and returns during extension of the strut. The size of the orifice is controlled by the movement of a tapered metering pin up and down through the orifice.

Whenever a load comes on the strut due to landing or taxiing and compression of the two strut halves starts, the piston (to which wheel and axle are attached) forces fluid through the orifice into the cylinder, where the rising fluid level compresses the air or nitrogen above it. When the strut has made sufficient stroke to absorb the energy of the impact, the air or nitrogen at the top expands and forces the fluid back. The slow metering of the fluid acts as a snubber, preventing rebounds. Instructions for servicing shock struts with hydraulic fluid and compressed air or nitrogen are contained on an instruction plate attached to the strut, as well as in the Maintenance Instructions Manual for the type aircraft involved. The shock absorbing qualities of a shock strut are heavily dependent on maintenance of proper air or nitrogen pressure and fluid level. (Shock strut servicing is covered in chapter 12.)

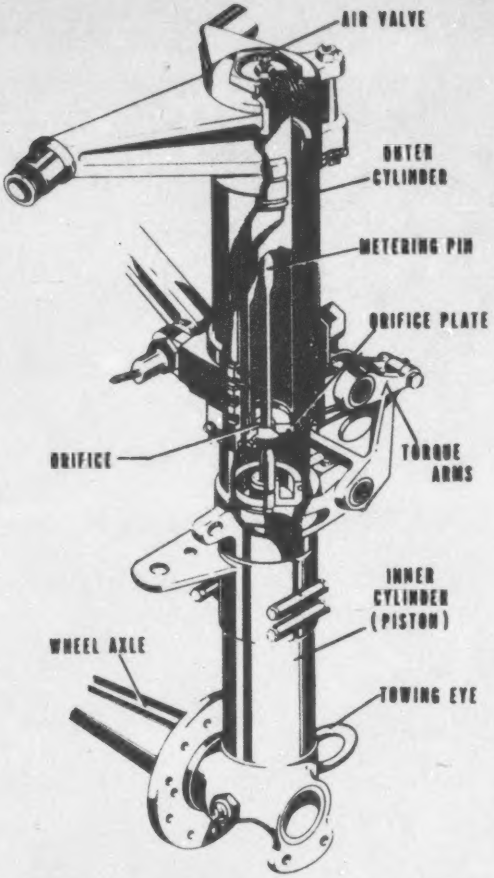
RETRACTING MECHANISMS.–Some aircraft have electrically actuated landing gear but most are hydraulically actuated. In figure 4-10, the retracting mechanism is hydraulically actuated and consists of an actuating cylinder, UP position and DOWN position locks, a safety switch, two position-indicating switches, and side struts and supports. The landing gear control handle in the cockpit allows the landing gear to be retracted or extended by directing hydraulic fluid under pressure to the actuating cylinder. The locks hold the gear in the desired position and the safety switch prevents accidental retracting of the gear when the aircraft is resting on its wheels.

A position indicator on the instrument panel



1. Side strut bearing support.
2. Truss member.
3. Fulcrum bearing support.
4. Spring-loaded cartridge.
5. Hydraulic actuating cylinder.
6. Downlock assembly.
7. Air valve.
8. Piston rod attachment fitting.
9. Shock strut.
10. Safety switch.
11. Torque arms.
12. Towing eye.
13. Brake assembly.
14. Lower side strut member.
15. Upper side strut member.

Figure 4-10.—Main landing gear assembly.



AM.242

Figure 4-11.—Shock strut, showing internal construction.

indicates the position of the landing gear to the pilot. The position indicator is operated by the position-indicating switches mounted on the UP and DOWN locks of each landing gear.

EMERGENCY EXTENTION.—Methods of extending the landing gear in the event of normal system failure vary with different models of aircraft. Most aircraft utilize an emergency hydraulic system. All others are pneumatic (compressed air or nitrogen), mechanical, gravity, or a combination of these systems.

Nose Gear

A typical nose gear assembly is shown in figure 4-12. Major components of the assembly include shock strut, drag struts, retracting mechanism, wheel, tire, tube, and shimmy damper.

The nose gear shock strut, drag struts, and retracting mechanism are all similar to those already described for the main landing gear.

The shimmy damper is a self-contained hydraulic unit which resists sudden twisting loads applied to the nosewheel during ground operation but does permit slow turning of the wheel. (See fig. 4-12.) The primary purpose of the shimmy damper is to prevent the nosewheel from shimmying (extremely fast left-right oscillations) during takeoff and landing. This is accomplished by the metering of hydraulic fluid through a small orifice between two cylinders or chambers.

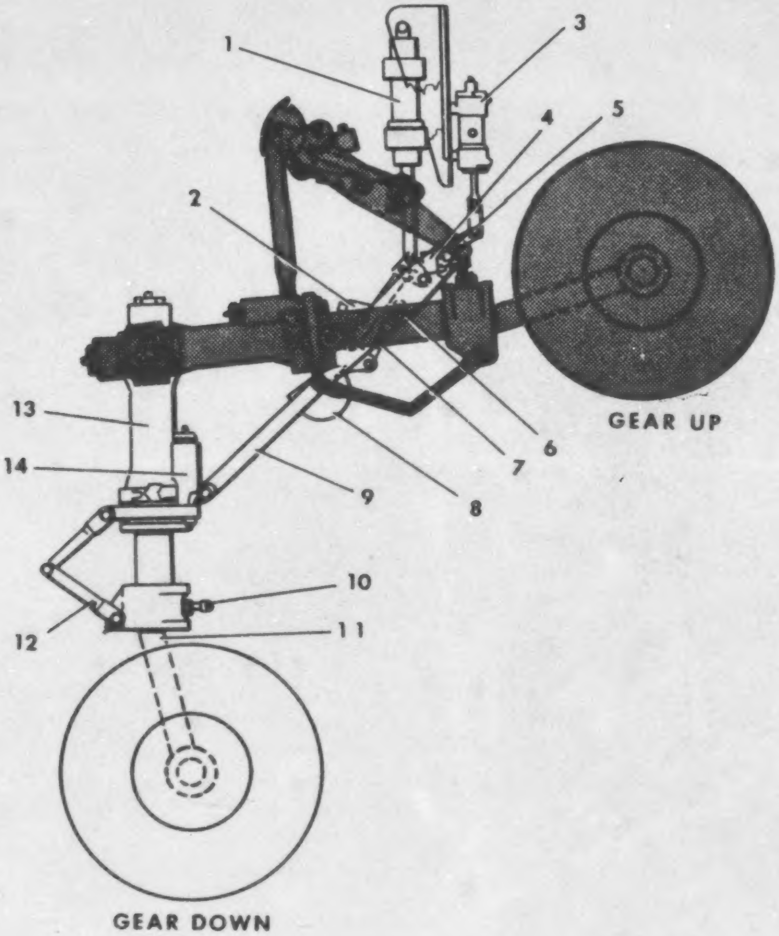
Some aircraft are equipped with steerable nosewheels and do not require a separate self-contained shimmy damper. In such cases, the steering mechanism is hydraulically controlled and incorporates two spring-loaded hydraulic steering cylinders which, in addition to serving as a steering mechanism, also automatically subdue shimmy and center the nosewheel.

Tail Gear

The tail gear assembly consists of a shock strut, retracting mechanism, wheel, tire, yoke, centering mechanism, and locking mechanism. The shock strut and retracting mechanism are similar to those described for the main landing gear.

The wheel is usually equipped with a solid rubber tire; however, some aircraft use a pneumatic tire on the tail wheel. The yoke usually consists of a fork or single arm of aluminum or steel, which link the wheel axle with the shock strut. The centering mechanism causes the tailwheel to caster to the trailing position during ground handling of the aircraft. It consists of a spring assembly which forces a roller against a cam mounted on top of the shock strut inner cylinder.

The locking mechanism is independent of the centering mechanism and is operated by a



AM.243

1. Hydraulic actuating cylinder.
2. Downlock switch.
3. Uplock cylinder.
4. Uplock switch.
5. Uplock.
6. Upper drag strut.
7. Downlock.
8. Cam.
9. Lower drag strut member.
10. Uplock engagement fitting.
11. Piston-axle.
12. Torque arms.
13. Shock strut cylinder.
14. Shimmy damper.

Figure 4-12.—Nose gear assembly.

control cable system connected to the tailwheel lock control lever in the cockpit. When the control lever is in LOCK position, the tailwheel is locked in the trailing position. LOCK position is used only during takeoff and landing. When the control lever is placed in UNLOCK, the tailwheel is free to swivel. This position must be used for taxiing and all other ground handling

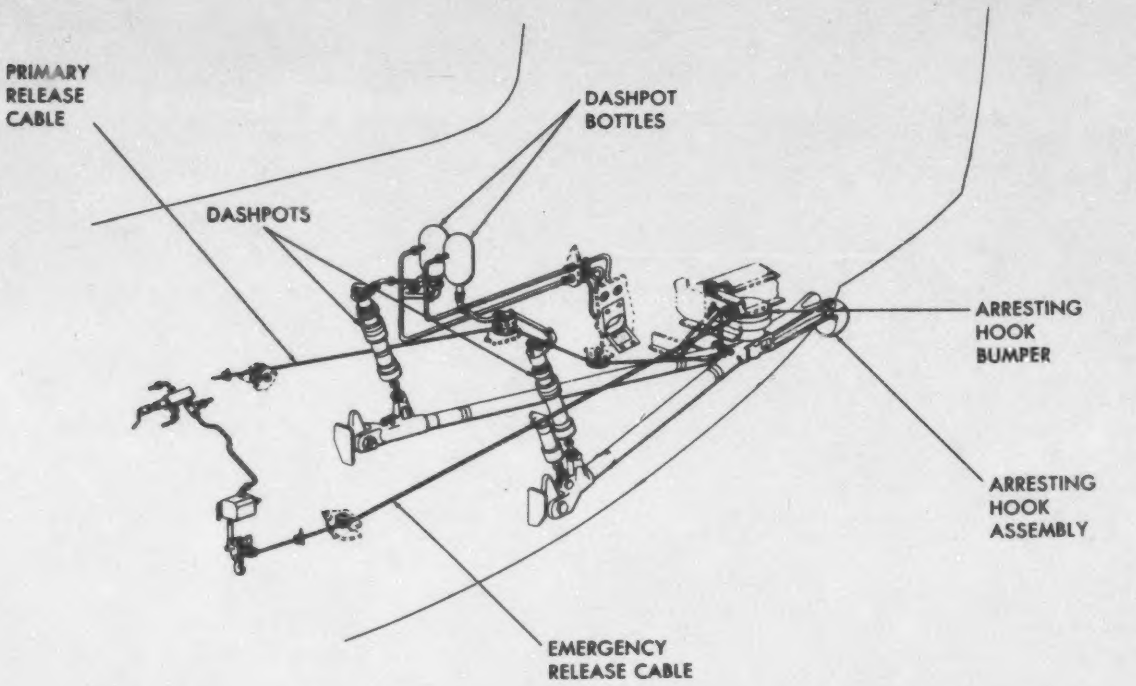


Figure 4-13.—Arresting gear installation.

operations. FAILURE TO OBSERVE THIS CAN RESULT IN SERIOUS STRUCTURAL DAMAGE.

Arresting Gear

The arresting gear shown in figure 4-13 consists of an arresting hook and its control mechanism. The hook generally consists of a steel shank and detachable steel point. The control mechanism is hydraulically operated. It is similar to the retracting mechanism for the landing gear, but is operated independently of the landing gear by a separate control in the cockpit. On some aircraft the arresting gear is electrically operated.

The aircraft arresting gear is a critical part of the aircraft equipment. In keeping with this importance, operating activities are required to maintain the appropriate logs, including the number of arrested landings on every arresting hook, and conduct specified inspection and regular replacement of hook points. Removed hooks are forwarded to the nearest naval air station that provides Depot maintenance support for inspection, test, and overhaul.

Tail Skag

Most aircraft having a tricycle type landing gear are equipped with a tail skag to protect the aft fuselage section from damage while landing, taxiing, or while being serviced.

The tail skag consists of a steel shoe or solid wheel, a conventional air-oil shock strut, retracting mechanism, and attachment fittings. The retracting mechanism operates simultaneously with the landing gear mechanism so that when the landing gear is lowered the tail skag is lowered, and when the landing gear is retracted the tail skag is retracted. Some aircraft are equipped with a stationary bumper in place of a retractable tail skag.

ROTARY-WING AIRCRAFT

The history of rotary-wing development embraces 500-year old efforts to produce a workable direct-lift-type flying machine. Man's early experiments in the helicopter field were fruitless. It is only within the last 30 years that encourgaging progress has been made, and it is within the past 20 years that production line helicopters have become a reality. Today, helicopters are found throughout the world, performing countless tasks especially suited to the unique capabilities of the modern-day version of the dream envisioned centuries ago by Leonardo da Vinci.

Da Vinci, who is recognized as the "Father of the Helicopter," made a series of drawings, with proper notations, which introduced the direct-lift principle of flight. The da Vinci Helix (as he termed his craft) was a spiral wing on a vertical shaft. It embodied the basic principles of the present-day helicopters. Da Vinci claimed that air had substance (we call it density), and that a spiral wing device, if turned at a sufficiently high speed, would bore up into the air much in the same fashion as an auger bores into wood.

Early in the development of rotary-wing aircraft, a need arose for a new word to designate this direct-lift flying device, and a resourceful Frenchman seized upon the two words, "Helis" which means screw or spiral, and "Pteron" which means wing. Combining these two words he fashioned the word "helicopter," which should be pronounced "hell-i-cop-ter."

A helicopter employs one or more power-driven horizontal air screws or rotors from which it derives lift and propulsion. If a single rotor is used, it is necessary to employ a means to counteract torque. If more than one rotor is used, torque can be "washed out" effectively by turning a combination of rotors in opposite directions.

The fundamental advantage the helicopters has over conventional aircraft is that lift and control are relatively independent of forward speed. A helicopter can fly forward, backward, or sideways, or remain in stationary flight above the ground (hover). No runway is required for a helicopter to takeoff or land. The roof of an office building is an adequate landing area. The helicopter is considered a safe aircraft because the takeoff and landing speed is practically zero.

As will be noticed during study of the following section concerning the construction of helicopters, they are in many ways similar to fixed-wing aircraft. The chapter concludes with a brief study of helicopter theory of flight.

FUSELAGE

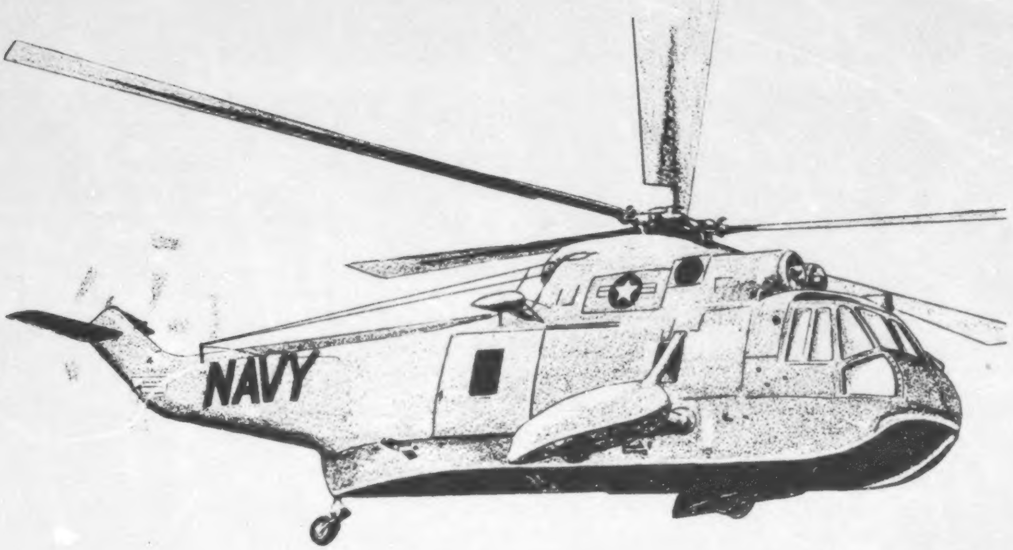
Like the fuselage in fixed-wing aircraft, helicopter fuselages may be welded truss or some form of monocoque construction. The welded truss fuselages predominate in the very small one- and two-place "choppers." Larger helicopters, characteristic of those designed for the military, run to the monocoque design.

A typical Navy helicopter, the H-3 aircraft built for the Navy by Sikorsky Aircraft, is illustrated in figure 4-14. A flying boat type hull provides this helicopter with water-operational capabilities for emergencies only. The fuselage consists of the entire airframe from the forward fuselage to the tail pylon. A cabin area occupies most of the forward fuselage not used for the flight deck (pilot and copilot compartment). The fuselage areas are sometimes known as the body group as is the case in the H-3.

The body group is of all metal semi-monocoque construction, consisting of aluminum alloy and titanium skin panels covering a reinforced aluminum alloy framework or skeleton. The skeleton of the lower fuselage consists of bulkheads, frames, and formers supported longitudinally (fore and aft) by a keel beam, chine angles, longerons, and stringers. The skeleton of the remainder of the body group consists of bulkheads and frames, which form the crosssectional shape, and longerons, intercostals (between rib stiffeners), and stringers which form the longitudinal contour.

LANDING GEAR GROUP

The landing gear group includes all the equipment necessary to support the helicopter when not in flight—conventional landing gear consisting of a right- and left-hand main landing gear



AM.245

Figure 4-14.–H-3 helicopter.

and a nonretractable tail landing gear plus right- and left-hand sponsons which house the main landing gear during flight and aid in stabilizing the aircraft during emergency operation from water when the aircraft is floating.

Main Landing Gear

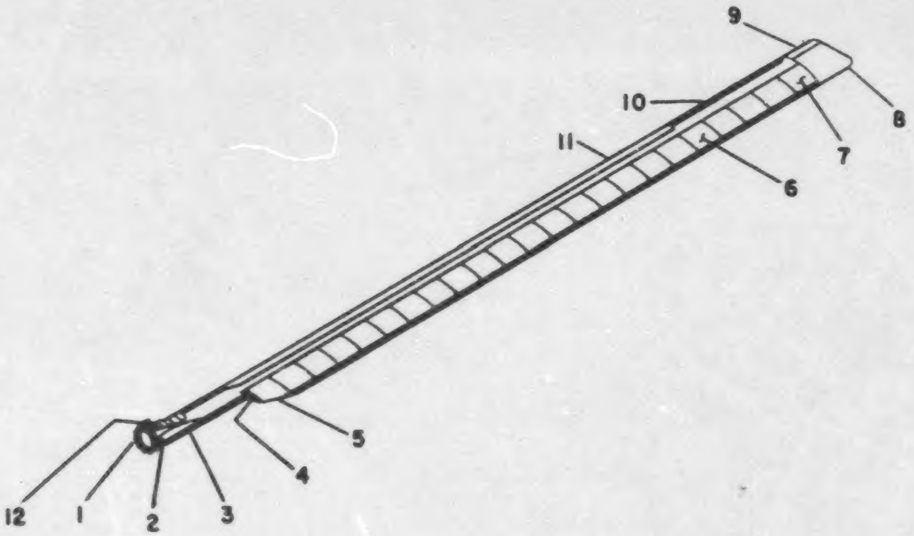
Each main landing gear is composed of a shock strut assembly, dual wheels, a retracting cylinder, an uplock cylinder, and upper and lower drag braces. The wheels retract into a well recessed into the underside of the sponsons. The dual wheels, equipped with tubeless tires and hydraulic brakes, are mounted on axles which are part of the lower end of the shock strut piston.

Normally, the main landing gear is extended hydraulically. However, in the case of hydraulic failure, an emergency system of compressed air may be used to lower the gear. Should the air system fail, a valve, actuated by the pilot, allows the gear to fall of its own weight.

Retractable alighting gear is not a feature common to all helicopters, nor even a majority of them. The H-3 is discussed here because it is one of the Navy's latest helicopter designs and it has the emergency water operational capability. The H-3 is illustrated in figure 4-14. Note the boat-shaped hull and the sponsons with landing gear extended from them. Most other helicopters have fixed tricycle alighting gear or a dual sled-like skid arrangement which eliminates the necessity for a nose or tail support.

Tail Landing Gear

The H-3 tail landing gear is nonretractable and full swiveling and serves as an aft touch-down point for land-based operations only. An air-oil type shock absorber unit, hinged to the yoke and shaft, cushions the landing shock. All components, with the exception of the axle and the shock absorber, are made from 7075-T6 aluminum alloy forgings.



1.	Cuff.	7.	Tip pocket.
2.	Plate.	8.	Tip cap.
3.	Spar.	9.	Abrasion strip.
4.	Root pocket cap.	10.	Abrasion strip.
5.	Root pocket.	11.	Ice guard.
6.	Pocket (typical).	12.	Bracket.

Figure 4-15.—Typical rotary wing blade.

MAIN ROTOR ASSEMBLY

The main rotor (rotary wing) and the rotor head are discussed in this section under the one heading because their functions are so closely related. Neither has a function without the other.

Rotary Wing

The main rotor or rotary wing of the H-3 is comprised of five identical wing blades. Other types of helicopter rotors may have two, three, or four blades. A typical wing blade is illustrated in figure 4-15.

The rotary wing blade illustrated in figure 4-15 is fabricated of aluminum alloy, with the exception of the forged steel cuff by which the blade is attached to the hub. The main supporting member of the blade is a hollow, aluminum alloy extruded spar which forms the leading edge. The steel cuff is bolted to the root end of the spar.

Twenty-three individual pockets, each constructed of aluminum ribs, an aluminum channel, and aluminum skin covering, are bonded to the aft edge of the spar. The tip end of the blade contains a readily removable tip cap, fastened to the spar and tip pocket rib by means of screws. The root pocket of the blade is sealed at its inboard end by an aluminum alloy root cap, cemented and riveted to the pocket.

A stainless steel abrasion strip is bonded to the leading edge of the spar from blade pocket No. 8 and extends along the entire leading edge, including the tip cap. Also, the blade illustrated is fitted with a deicing guard. The guard is composed of fine wire braid heating elements, interwoven in bands and embedded in a rubber strap to which is bonded a stainless steel strap. The guard is bonded to the leading edge of the spar and is molded to the contour of the blade.

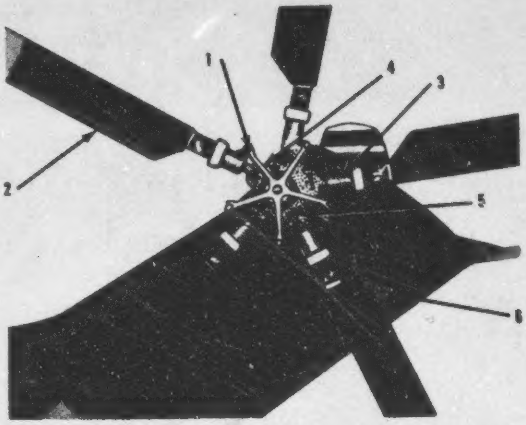
Rotor Head

The rotary wing head is splined to, and supported by, the rotary wing shaft of the main gearbox. The head supports the rotary wing blades, is rotated by torque from the main gearbox, and transmits movements of the flight controls to the blades.

The principal components of the head are the hub and swashplate. The hub consists of a hub plate and lower plate; hinges, between each arm of the plates; sleeve-spindles which are attached to the hinges; and a damper-positioner for each wing blade. The swashplate consists of a rotating swashplate and stationary swashplate. Other components of the rotary wing head are anti-flapping restrainers, droop restrainers, adjustable pitch control rods, and rotating and stationary scissors.

The swashplate and adjustable pitch control rods permit movement of the flight controls to be transmitted to the rotary wing blades. The hinges allow limited movement to the blades in relation to the hub. These movements are known as LEAD, LAG, and FLAP. LEAD occurs during slowing of the drive mechanism when the blades have a tendency to remain in motion. LAG is the opposite of LEAD and occurs during acceleration when the blade has been at rest and tends to remain at rest. FLAP is the tendency of the blade to rise with high lift demands as it tries to screw itself upward into the air. The damper-positioners restrict lead and lag motion and position the blades in preparation for folding. Sleeve-spindles allow each blade to be rotated on its spanwise axis to change the blade pitch. The anti-flapping restrainers and droop restrainers restrict flapping motion when the rotary wing head is slowing or stopped.

TAIL ROTOR GROUP



AM.247

1. Pitch link.
2. Rotary rudder blade.
3. Spindle.
4. Pitch control beam.
5. Rotary rudder hub.
6. Pylon.

Figure 4-16.—Tail rotor group.

The tail rotor group (fig. 4-16) is comprised of those helicopter components that provide the aircraft with directional control. These are pylon, rotary rudder blades, and rotary rudder head. The rotary rudder head includes such items as the hub, spindle, and pitch control beams.

Pylon

The pylon illustrated in figure 4-16 is of aluminum semimonocoque construction, and is composed of beams, bulkheads, stringers, formers, and channels. Various gages of aluminum skin located on the left- and right-hand sides of the box structure are part of the primary pylon structure. Reinforced plastic fairings in the leading and aft surfaces forming the airfoil contour of the pylon are considered to be secondary structure.

The pylon houses an intermediate gearbox and the tail gearbox. The pylon is attached on the right side of the aircraft to the main fuselage by hinge fittings. These hinge fittings also serve as the pivot point for the pylon to fold alongside the right side of the rear fuselage. Folding of the pylon reduces the overall length of the H-3 helicopter by 7 1/2 feet, thereby greatly facilitating its handling, particularly aboard ship.

Rotary Rudder Head

The rudder head, usually located on the left side of the pylon, produces anti-torque forces which may be varied by the pilot to control flight heading. The rotary rudder head is driven by the tail gearbox. Change in blade pitch is accomplished through the pitch change shaft that moves through the horizontal shaft of the tail gearbox. As the shaft moves inward toward the tail gearbox, pitch of the blade is decreased. As the shaft moves outward from the tail gearbox, pitch of the blade is increased. The pitch control beam is connected by links to the forked brackets on the blade sleeves.

A flapping spindle for each blade permits flapping of the blade to a maximum of 10 degrees in each direction.

Rotary Rudder Blades

The blades are on the rotary rudder head. Each blade consists of an aluminum spar, an aluminum pocket with honeycomb core, an aluminum tip cap, an aluminum trailing edge cap, and an abrasion strip. In addition, those blades that have de-icing provisions have a neoprene anti-icing guard, embedded with electrical heating elements. The root end of the blade permits attaching to the rotary rudder head spindles. The abrasion strip protects the leading edge of the blade, or the de-icing guard, from sand, dust, and adverse weather conditions. The skin is wrapped completely around the spar, and the trailing edge cap is installed over the edges of the skin at the trailing edge of the blade. The tip cap is riveted to the outboard end of the blade.

THEORY OF FLIGHT

At this point it is assumed that the AMSAN or AMS3 who is studying for advancement in rating is familiar with theory of flight and its application to fixed-wing aircraft. (Review NavPers 10307-C, Airman.) Therefore, this chapter contains no extended discussion of the basic principles involved in the aerodynamics of flight. Instead, there is but brief mention of the principles themselves, with the major emphasis on their application to the helicopter.

Although in many respects the helicopter differs radically from the conventional aircraft, rotary-wing aerodynamics is not something entirely new and different from fixed-wing aerodynamics. The same basic principles apply to both aircraft. During flight, the two types of aircraft are subjected to many of the same forces and affected by many of the same reactions. In short, the principles involved in rotary-wing aerodynamics are those basic principles with which the Aviation Structural Mechanic S Third Class or Striker has already learned while preparing himself for advancement to Airman.

In flight, both conventional aircraft and the helicopter are acted upon by four basic forces—WEIGHT, LIFT, THRUST, and DRAG. In addition, both types of aircraft are affected by torque reaction.

LIFT.—Weight and lift are closely related in that weight tends to pull the aircraft—or helicopter—down, and lift holds it up. Right here is where the basic similarity between the helicopter and the airplane begins; both aircraft are heavier than air and both are supported by the reactions of airfoils to air passing over them. This reaction, or lift, is a result of pressure differential. The pressure on the upper surface of the supporting airfoil is less than atmospheric, while the pressure on the lower surface is equal to, or greater than, atmospheric.

The conventional aircraft's airfoils are, of course, the wings. The helicopter's airfoils are the rotor blades. One aircraft has fixed wings and the other rotary wings, but the same basic principles of lift apply to both.

The length, width, and shape of an airfoil all affect its lifting capacity. However, for any one airfoil there are but two primary factors affecting the amount of lift the airfoil will develop. The relation between these two factors—velocity of airflow and angle of attack—and their effect on lift can be expressed as follows:

For a given angle of attack, the greater the speed, the greater the lift.

For a given speed, the greater the angle of attack (up to the stalling angle), the greater the lift.

Thus, lift can be varied by varying either one of these two factors. Furthermore, increasing either speed or angle of attack, or both, (up to certain limits) increases lift.

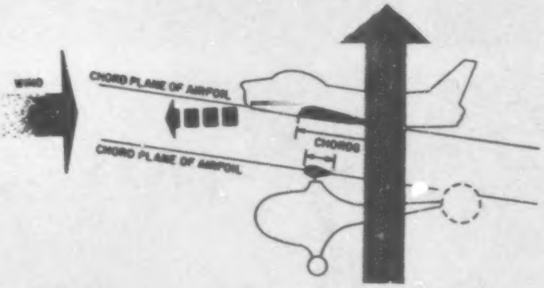
Velocity of Airflow.–Not only is velocity of airflow a primary factor affecting lift, but a certain minimum velocity is required in order that the airfoils may develop sufficient lift to get either an airplane or a helicopter into the air and keep it there. This means that for either the airplane or the helicopter, the airfoils must be moved through the air at a relatively high speed.

In the conventional aircraft the required flow of air over the airfoils can be obtained only by moving the entire aircraft forward. If the wings must move through the air at 100 miles per hour to produce sufficient lift to support the aircraft in flight, then the fuselage and all other parts of the aircraft must move forward at that same speed. This means that the aircraft must takeoff, fly, and land at relatively high speeds. Furthermore, it means that the aircraft is limited to forward flight; it cannot fly backwards or sideways.

The helicopter's airfoils must also move through the air at comparatively high speed to produce sufficient lift to raise the aircraft off the ground or keep it in the air. But here, the required speed is obtained by rotating the airfoils. Furthermore, the rotor can turn at the required takeoff speed while the fuselage speed remains at zero.

Thus, the speed of the airfoils (rotor blades), and the resultant velocity of airflow over them, is independent of fuselage speed. As a result, the helicopter does not require high forward speeds of the entire aircraft for takeoff, flight, and landing. Nor is it limited to forward flight. It can rise vertically. It can fly forward, backward, or sideways as the pilot desires. It can even remain stationary in the air while the rotating airfoils develop sufficient lift to support the aircraft. In fact, all of these kinds of flight are normal for the helicopter.

Angle of Attack.–Velocity of airflow around an airfoil is but one of the factors affecting lift. The other factor is angle of attack. For either an airplane wing or a helicopter rotor blade, the angle of attack is the angle formed by the chord plane of the airfoil and the relative wind, as shown in figure 4-17.



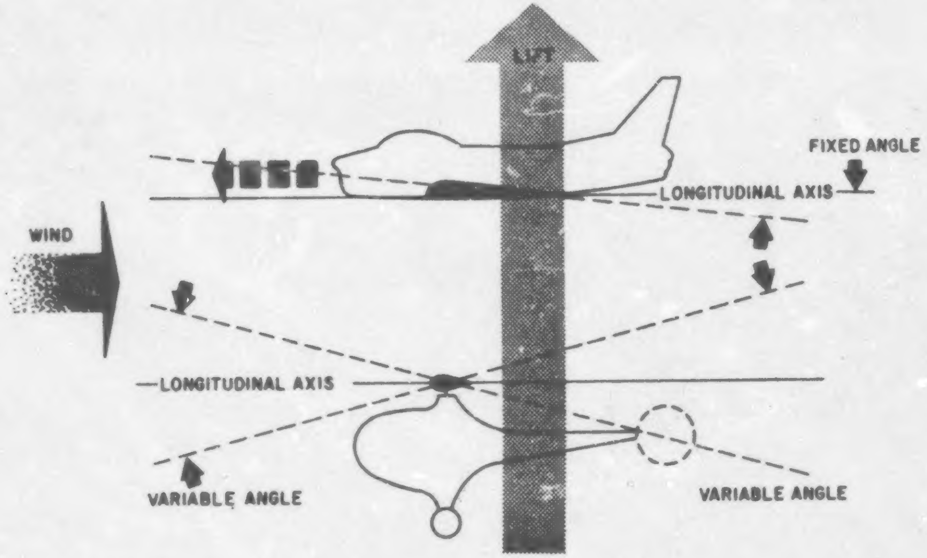
AM.248

Figure 4-17.–Chord planes of airfoils.

With the conventional aircraft, the angle of attack can be varied only by changing the attitude of the entire aircraft (F-8 excepted). When, for example, the pilot wishes to climb, he pulls back on the control stick or column so that the aircraft will take a nose-high attitude, thereby increasing both angle of attack and lift. When he reaches the desired altitude, he levels off to decrease the angle of attack. When he wishes to descend, he pushes forward on the stick or column, causing the aircraft to take a nose-low attitude.

The pilot can increase or decrease the helicopter's angle of attack without changing the attitude of the fuselage. He does this by changing the pitch of the rotor blades by means of a cockpit control provided for this purpose. In fact, under certain flight conditions, the angle of attack continually changes as the rotor blade turns 360 degrees. This occurs whenever the rotor plane of rotation is tilted, as it is during forward, backward, and sideways flight. This tilting of the plane of rotation of the main rotor and the aerodynamics of the various kinds of flight are discussed later. (Plane or rotation is also known as the tip path plane and includes that area swept by the rotating blades.)

Angle of Incidence.–For the airplane, the final value of the angle of attack depends on the attitude of the airplane and one other factor–the angle of incidence. The angle of incidence,



AM.249

Figure 4-18.—Angles of incidence.

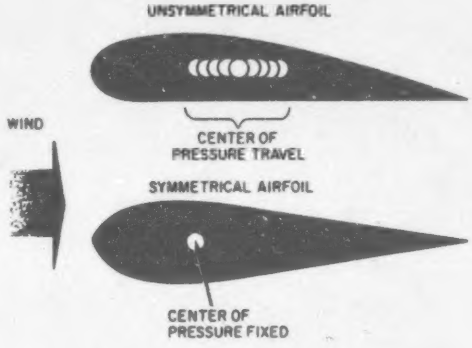
for either an airplane or helicopter, is the angle formed by the chord of the airfoil and the longitudinal axis of the aircraft. The longitudinal axis of a helicopter is a line at right angles to the main rotor drive shaft.

The conventional aircraft's angle of incidence is determined by the designer and is built into the aircraft. The angle of incidence cannot be changed by the pilot.

The helicopter's angle of incidence can be changed at will by the pilot—by changing the pitch of the rotor blades. Like the angle of attack, the angle of incidence continually changes as the rotor revolves whenever the control stick is moved from the neutral position and the rotor plane of rotation is tilted. Note the comparative angles of incidence, as sketched in figure 4-18.

AIRFOIL SECTION.—Airfoil sections used for airplane wings vary considerably—each being selected to meet specific requirements. The airfoil may be symmetrical or unsymmetrical, like the ones shown in figure 4-19.

An unsymmetrical airfoil may be efficient for an airplane wing, but it has one disadvantage that makes it unsatisfactory for use as a rotor blade. The center of pressure "walks" forward



AM.250

Figure 4-19.—Center of pressure.

and rearward as the angle of attack changes. The center of pressure is an imaginary point on the airfoil where all of the aerodynamic forces are considered as being concentrated. On an unsymmetrical airfoil the center of pressure is toward the rear of the wing at small angles of attack and moves forward as the angle of attack is increased. This forward movement continues until the angle of attack is approximately the same as the angle of maximum lift coefficient. (The angle of maximum lift coefficient is that angle at which 1 square foot of airfoil travelling at 1 mile per hour will produce the greatest possible lift.)

The center of pressure cannot be permitted to walk back and forth on a helicopter rotor blade, since shifting of the center of pressure would introduce pitch-changing forces. This would be undesirable–and dangerous. Therefore, the center-of-pressure travel is controlled by airfoil design and is usually at a point 25 percent back from the leading edge of the rotor blade. A symmetrical airfoil has the desirable characteristic of limiting center-of-pressure travel.

THRUST AND DRAG.–Like weight and lift, thrust and drag are closely related. Thrust moves the aircraft in the desired direction; drag tends to hold it back.

The conventional aircraft's thrust is, in general, forward, and drag to the rear. These forces always act in opposite directions and are usually horizontal, or only slightly inclined from the horizontal. Seldom, if ever, do these forces approach the vertical. Furthermore, the conventional aircraft's thrust can be separated and considered apart from lift. The propeller (or jet) is responsible for thrust; the wings are responsible for lift.

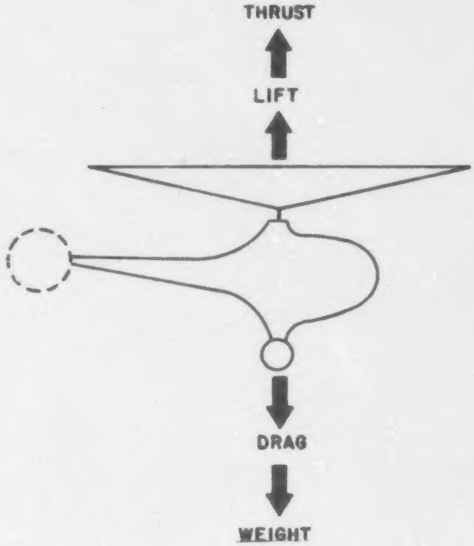
The helicopter gets both its lift and thrust from the main rotor. In vertical ascent, thrust acts upward in a vertical direction, while drag, the opposing force, acts vertically downward. In forward flight, thrust is forward and drag to the rear. In rearward flight, the two are reversed. In short, thrust acts in the direction of flight and drag acts in the opposite direction.

The thrust and drag forces and two of these conditions–vertical flight and forward flight–are discussed in the following paragraphs. These discussions deal with the thrust and drag forces acting on the fuselage, not with the forces within the rotor system.

During vertical ascent, thrust acts vertically upward while drag acts vertically downward. Here the drag opposing the upward motion of the helicopter is increased by the down-wash of air from the main rotor. Thrust must be sufficient to overcome both of these forces which make up the total drag. In the illustration (fig. 4-20), note that thrust acts in the same direction and in line with lift. Furthermore, the main rotor is responsible for both thrust and lift. Therefore, the force representing the total reaction of the airfoils to the air may be considered as being divided into two components. One component, lift, is the force required to support the weight of the helicopter. The other component, thrust, is the force required to overcome the drag on the fuselage. But drag is a separate force from weight, as is indicated in figure 4-20.

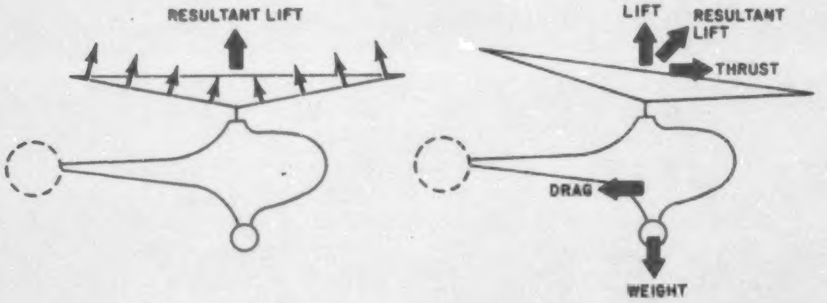
Now let us examine the thrust and drag forces acting on the fuselage during forward flight.

In any kind of flight–vertical, forward, backward, sideways, or hovering–the resultant lift



AM.251

Figure 4-20.–Alignment of forces during vertical ascent.



AM.252

Figure 4-21.—Transition from vertical to forward flight.

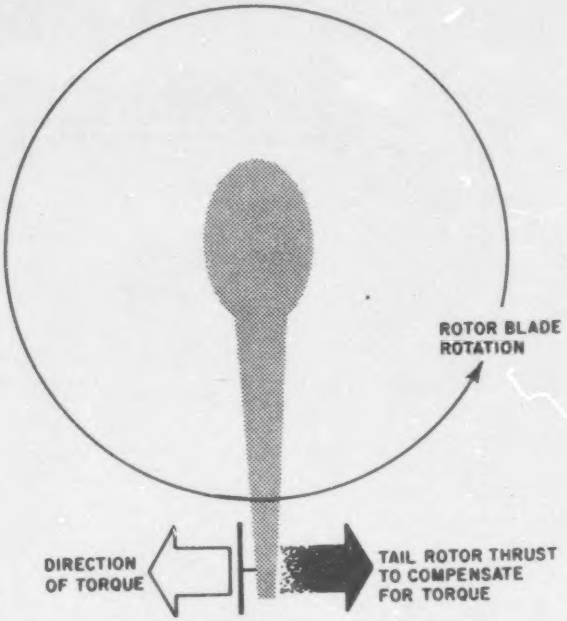
forces of a rotor system are perpendicular to the tip path plane (plane of rotation). Remember, the tip path plane is the imaginary plane described by the tips of the blades in making a cycle of rotation. During vertical ascent or hovering, the tip path plane is horizontal and this resultant force acts vertically upward, as shown in figure 4-21. To accomplish forward flight, the pilot tilts the tip path plane forward. The resultant force tilts forward with the rotor as shown in the illustration. The total force, now being inclined from the vertical, acts both upward and forward; therefore, it can be resolved into two components as shown in the illustration. One component is lift, which is equal to and opposite weight. The other component, thrust, acts in the direction of flight to move the helicopter forward.

Although this discussion covers only two flight conditions, it should point the way to a basic understanding of thrust and drag forces acting on the helicopter fuselage during flight. In rearward flight, the thrust and drag forces are similar to those in forward flight, but are reversed. The tip path plane is tilted to the rear, the thrust component acts to the rear, and drag opposes the rearward motion of the aircraft. In sideways flight, the pilot tilts the tip path plane in the desired direction of flight, thrust is to the right or left in the direction of flight, and drag acts in the opposite direction.

TORQUE.—As the helicopter rotor turns in one direction, the fuselage tends to rotate in the opposite direction. This torque effect is in accord with Newton's third law of motion which states that, "To every action there is an opposite and equal reaction." In the helicopter, the reaction is in a direction opposite to that in which the rotor is driven by the engine and is proportional in magnitude to the power being delivered by the engine.

Torque is of real concern to both the designer and pilot. There must be provisions for counteracting torque and for positive control over its effect during flight. On dual-rotor and coaxial-rotor helicopters, the rotors turn in opposite directions, thus "washing out" torque reaction. In jet helicopters with engines mounted on the main rotor blade tips, the power is initiated at the rotor blade; therefore, the reaction is between the blade and the air, with no torque reaction between the rotor and the fuselage. Therefore, it is in helicopters of the single main rotor configuration that torque presents a problem to the pilot during flight.

The usual way of counteracting torque in a single main rotor helicopter is by means of an antitorque rotor. This axuiliary rotor is mounted vertically on the outer portion of the tail boom. Turning at a constant rpm, usually slightly higher than one-half engine speed, the tail rotor produces thrust in a horizontal plane, opposite in direction to the torque reaction developed by the main rotor. Figure 4-22 shows the direction



AM.253

Figure 4-22.–Torque reaction and compensation.

of the torque reaction and the direction of tail rotor thrust for a helicopter in which the main rotor turns from the pilot's right, to his front, to his left, and then to his rear. Most single rotor systems turn in this direction.

Since the torque effect on the fuselage is a result of the engine power supplied to the main rotor, any change in engine power brings about a corresponding change in the torque effect. Furthermore, power requirements vary with flight conditions. Therefore, the torque effect is not constant but varies during flight. This means that there must be some provision for varying tail rotor thrust. Usually, a variablepitch tail rotor is employed and rudder pedals are linked by cables with the pitch change mechanism in the tail rotor head. This permits the pilot to increase or decrease tail rotor thrust, as required, to neutralize the torque effect.

The tail rotor and its controls serve as both a means of counteracting torque effect and a means of heading the helicopter in the desired direction of flight. Therefore, the tail rotor control pedals serve as rudder pedals. The effect of the tail rotor controls is shown in figure 4-23. Applying left rudder causes the nose of the helicopter to turn to the left; applying right rudder causes the nose to swing to the right. When the pilot wishes to maintain a constant heading, he keeps just enough pitch in the tail rotor to neutralize torque effect.

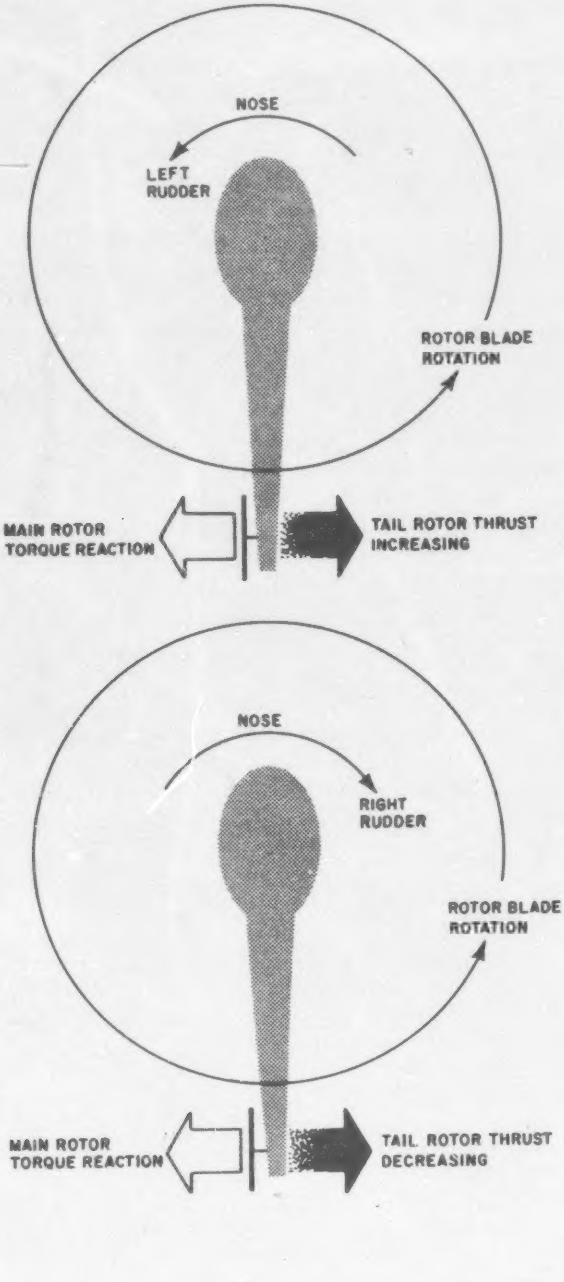
Although the tail rotor is the primary means of counteracting and controlling torque, the tail rotor alone does not quite do the job. This is true because torque cannot be compensated for by a single force. The tail rotor alone would prevent rotation of the fuselage, but would cause TRANSLATION (movement in a lateral direction) of the helicopter, during hovering, in the direction of tail rotor thrust.

Complete compensation for torque requires a COUPLE–a pair of equal forces acting in opposite directions. Tail rotor thrust constitutes one of the forces. The second force is introduced by rigging the helicopter with the tip path plane tilted from 1 to 2 1/2 degrees to the left, depending upon the helicopter. Figure 4-24 shows the balance of forces on a helicopter employing a single right-to-left main rotor. Note that the slight tilt of the tip path plane to the left results in a thrust force to the left. This force and tail rotor thrust form the couple required to completely compensate for torque.

Hovering

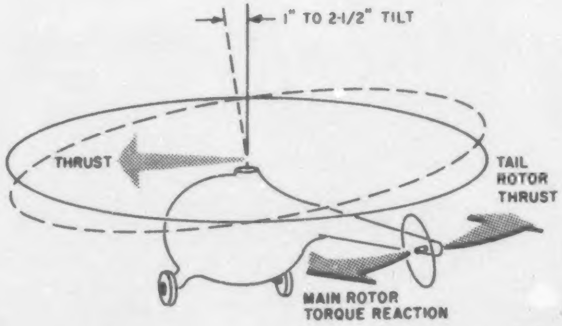
Hovering is the maintaining of a position above a fixed spot on the ground, usually at an altitude of about 8 feet. Helicopters normally hover on takeoffs and landings.

For the helicopter to hover, its main rotor must supply lift equal to the helicopter's weight. Lift is controlled by controlling the pitch of the rotor blades. As the blades rotate, air flows across the leading edge of each blade in the direction indicated in figure 4-25. The airflow crosses the leading edge of each blade throughout the complete rotational cycle of 360 degrees. At the same time the blades have a tendency to screw upward into the air, and air flows down through the rotor system from above as shown in figure 4-26.


NOSE
LEFT RUDDER
ROTOR BLADE ROTATION
MAIN ROTOR TORQUE REACTION
TAIL ROTOR THRUST INCREASING
NOSE
RIGHT RUDDER
ROTOR BLADE ROTATION
MAIN ROTOR TORQUE REACTION
TAIL ROTOR THRUST DECREASING

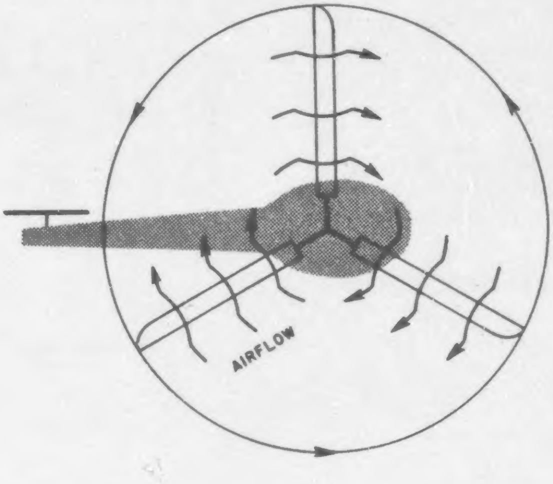
AM.254

Figure 4-23.—Effect of tail rotor pitch changes on heading.



AM.255

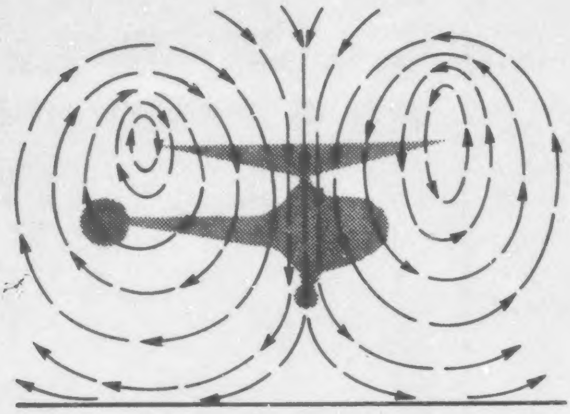
Figure 4-24.—Balance of forces on a helicopter.



AM.256

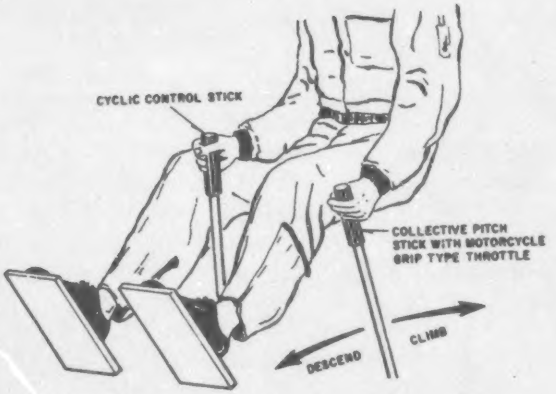
Figure 4-25.—Airflow across blades.

The pitch and rpm of the rotor blade are controlled by the COLLECTIVE PITCH stick. Control by this stick affects all the blades collectively. The normal location of this control is shown in figure 4-27. By raising or lowering the collective pitch stick one can change the collective pitch—the pitch on all of the main



AM.257

Figure 4-26.—Airflow through blades.


CYCLIC CONTROL STICK
COLLECTIVE PITCH STICK WITH MOTORCYCLE GRIP TYPE THROTTLE
CLIMB
DESCEND

AM.258

Figure 4-27.—Main rotor pitch controls.

rotor blades—the same amount. Raising the stick increases the pitch; lowering it decreases the pitch. If the rotor rpm remains constant, increasing or decreasing the blade pitch causes the helicopter to climb or descend.

To maintain constant rotor rpm during pitch change, a built-in synchronization unit is linked from the bottom of the collective pitch stick to the carburetor by a series of push-pull rods. As the blade pitch is increased, calling for more engine power to maintain a constant rotor rpm, the synchronization unit opens the throttle. The opposite is also true, of course. If the blade pitch is decreased, less engine power is required for the same rotor rpm, so the synchronization unit acts to reduce engine power.

On the upper end of the collective pitch stick is a motorcyclegrip type throttle, with which the throttle can be "rolled on" or "rolled off" if the synchronization unit does not maintain exact engine rpm. This hand throttle permits overriding of the synchronization unit in making the final adjustments to obtain the specified engine rpm.

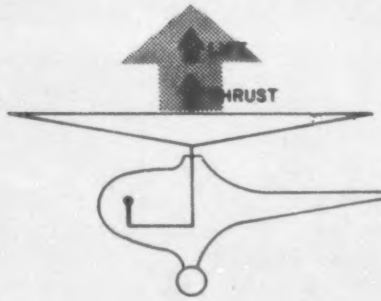
Directional Flight

Directional flight of a helicopter demands pilot coordination to properly execute the desired flightpath. The helicopter can fly either vertically, horizontally, or a combination of the two directions. Both vertical and horizontal flight are discussed in the following paragraphs.

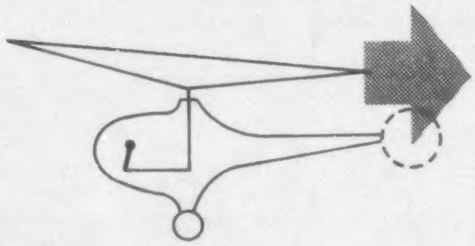
VERTICAL FLIGHT.—Vertical flight is controlled exactly the same way as hovering, since hovering is an element of vertical flight. To climb, the collective pitch stick is raised, using the throttle on the pitch stick to make any rpm adjustments not made automatically. At the same time, the cyclic control (discussed under "Horizontal Flight") is held in a vertical position, so that lift will be vertical. The flow of air is still over the leading edge of each blade, but the helicopter is now moving upward as shown in figure 4-28.

When the helicopter is climbing vertically the main rotor supplies not only the lift necessary to support the helicopter's weight, but also the thrust necessary to cause the helicopter to rise vertically. To descend, the collective pitch stick is lowered to decrease main rotor pitch and the resultant lift.

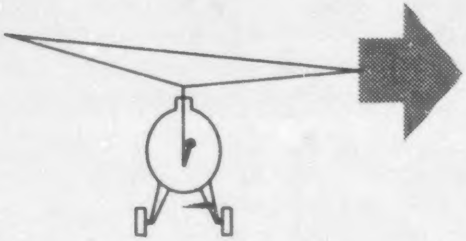
HORIZONTAL FLIGHT.—Horizontal flight is controlled by tilting the tip path plane in the direction of desired flight—forward, backward, to the left, or to the right. As detailed in figure 4-28, the helicopter moves in the direction the tip path plane is tilted.



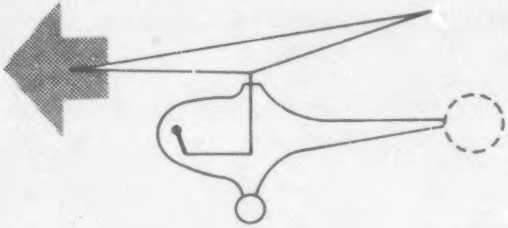
VERTICAL FLIGHT



BACKWARD FLIGHT



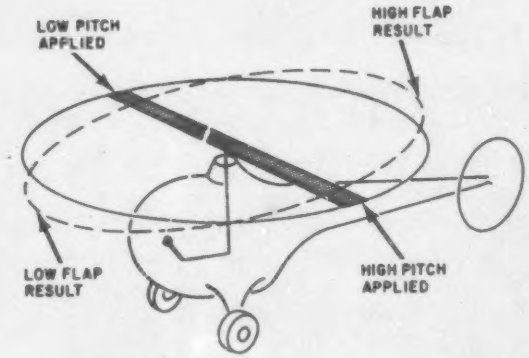
SIDEWARD FLIGHT



FORWARD FLIGHT

AM.259

Figure 4-28.—Directional flight attitudes.



AM.260

Figure 4-29.—Pitch changes for forward flight.

The pilot tilts the tip path plane by means of the cyclic pitch control. This control provides a mechanical means of changing the pitch of the main rotor blades in any direction of tilt throughout their full 360 degrees of rotation. Cyclic pitch change is equal and opposite, as shown in figure 4-29. If the blade pitch is increased 3 degrees on one side of the rotor center, at a point 180 degrees around the cycle of rotation, the blade pitch is decreased 3 degrees.

For every pitch change there is a resulting flapping action of the individual blades, as they constantly change pitch during rotation. As is shown, maximum flapping takes place 90 degrees around the cycle of rotation from the place where the pitch change was applied. The equal and opposite pitch change and the resulting flapping of the individual blades causes the tip path plane to tilt in the same direction as the pilot moves the cyclic control stick. Thus, to fly forward, backward, sideways, or in fact, any direction horizontally, all that is required is to tilt the cyclic control stick in the desired direction.

To climb or descend while moving forward, backward, or to either side, is merely a matter of coordinating the movements of the collective pitch control, which governs vertical flight; and the cycle control, which governs horizontal flight.

CHAPTER 5

SHEET-METAL WORKING MACHINES, TOOLS, AND PROCEDURES

TOOLS

The AMS3 and AMS2 must have a thorough knowledge of the tools of his trade to enable him to increase his performance and the quality of his products. Using this knowledge and applying it in the right direction will aid in increasing the squadron's efficiency and operational availability. One of the most important factors that a mechanic can have is the ability to use the tools which are required to complete any given task in a skilled and technical manner.

A mechanic is known by the tools he keeps. The use of tools may vary; but safety, good care, and the proper stowage of tools never vary. In this chapter, some of the various tools that the AMS uses in the course of his duties are briefly described. The Rate Training Manuals, Tools and Their Uses, NavPers 10085 (Series), and Airman, NavPers 10307 (Series), also contain a description of most of the tools used by the AMS, together with detailed instructions for using them. The material given in this chapter is intended to supplement, rather than repeat, the information given in Tools and Their Uses and the Airman manuals.

PROCUREMENT

Some activities have a centrally located toolroom which procures tools for the activity as a whole. This allows for better usage and accountability of the equipment. An activity's alloted amount of handtools is in accordance with an allowance which is established by NavAir 00-35QG-016, Consumable General Support Equipment for All Types, Classes, and Models of Aircraft, and the Individual Material Readiness List (IMRL).

NavAir 00-35QG-016 includes all of the accountable and consumable general support equipment which is required for the maintenance and operation of all types of aircraft at the Intermediate and Organizational levels of maintenance. Most of the tools listed in NavAir 00-35QG-016, appropriate for use by the AMS, are found in the toolbox he is issued.

The Individual Material Readiness List (IMRL), which applies to an activity by name, specifies items and quantities of aircraft ground support equipment required for material readiness of the aircraft maintained by the activity.

Whenever the number of tools in the activity falls below a certain minimum, the central toolroom supervisor reorders to replenish his stock. The quantity status of tools on hand is determined by regular inventories.

CUSTODY

When it becomes necessary or desirable for an AMS to have a toolbox assigned to him on a custody basis, the shop supervisor will notify the toolroom personnel to issue an AMS toolbox to the designated person. Normally, the central toolroom will have a locally prepared toolbox inventory form. This form will be applicable to the particular aircraft, equipment, and maintenance level to be supported. They will issue the toolbox in accordance with this inventory form, making two copies—one (master copy) to be held by the central toolroom, and one to be placed in the toolbox in a grease-resistant envelope. The AMS should use this copy to inventory his toolbox after completion of each assigned task to insure that all of his tools have been placed back in his toolbox.

NOTE: Reinventory of tools taken to the jobs is a MUST to eliminate the possibility of damage to the aircraft due to foreign objects left adrift within or around the aircraft.

INVENTORY

The AMS who has custody of a toolbox must prevent the loss of tools through neglect or misuse. Although handtools are normally classed as consumable items, they are very expensive and must be paid for when lost or carelessly damaged. One method of preventing loss of tools is a thorough inventory after each job assignment. Usually, the activity will have a local instruction concerning the inventory interval and method of reporting lost or damaged tools.

NOTE: Broken or damaged tools can damage aircraft hardware and parts. They can also cause personal injury to the worker or others.

At the periodic inventory, which is normally performed by central toolroom personnel, all broken or missing tools should be replaced. Nonproductive time between job assignments provides ample time for further inspection and upkeep of toolboxes. Someone has said "show me a mechanic with a poor toolbox and I will show you a poor mechanic."

In addition to the tools normally issued with the toolbox, there are many special tools an AMS3 or AMS2 will come in contact with and use. Later in this chapter we will discuss just a few of these tools. Special tools are normally kept in the central toolroom and signed out on an as-needed basis. These tools are returned to the toolroom as soon as the AMS has completed his work assignment. (Tools should be returned no later than the same day as checked out.)

Each activity has an allowance of special tools which they may have on custody. Often the allowance for an item is only one, which means positive control must be exercised. The special tools allowance list for a particular aircraft on which the AMS might be working is contained in the activity's Individual Material Readiness List (IMRL) publications.

Some of the newer aircraft manuals list the special tools and equipment in one section of the Illustrated Parts Breakdown; for example, NavAir 01-75PAA-4-13, P-3A Special Support Equipment, and NavAir 01-24FDA-4-6, F-4A Special Support Equipment. When determining special support equipment allowances for any activity, refer to the Individual Material Readiness List.

HANDTOOLS

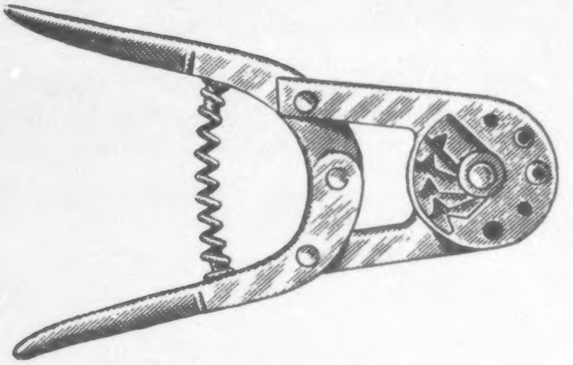
Before discussing the tools individually, a few comments on the care and handling of handtools in general might be appropriate. The condition in which an AMS maintains his assigned tools determines his efficiency as well as affecting the judgment that his superiors pass upon him in his day-to-day work. A mechanic is always judged heavily by the manner in which he handles his tools.

Each mechanic should keep all his assigned tools in his toolbox when he is not actually using them. He should have a place for every tool, and every tool should be kept in its place. All tools should be cleaned after every use and before being placed in the toolbox. If they are not to be used again the same day, they should be oiled with a light preservative oil to prevent rusting. Tools that are being used at a workbench or at a machine should be kept in easy reach of the mechanic, but should be kept where they will not fall or be knocked to the deck Tools should not be placed on finished parts or machines.

RIVETING TOOLS

Rotary Rivet Cutters

In case one cannot obtain rivets of the required length, rotary rivet cutters (fig. 5-1) are used to cut longer rivets to the desired length. When using the rotary rivet cutter, insert the rivet part way into the correct diameter hole, place the required number of shims (shown as staggered, notched strips in the illustration) under the head, and squeeze the handles. The compound action from the handles rotates the two discs in opposite directions. Rotation of discs shears the rivet smoothly to give the correct length (as determined by the number of



AM.290

Figure 5-1.–Rotary rivet cutter.

shims inserted under the head). When using the larger cutter holes, place one of the tool handles in a vise, insert the rivet in the hole, and shear it by pulling the free handle. If this tool is not available, diagonal cutting pliers can be used as an emergency cutter although the sheared edges will not be as smooth and even as when cut with the rotary rivet cutter.

Rivet Set

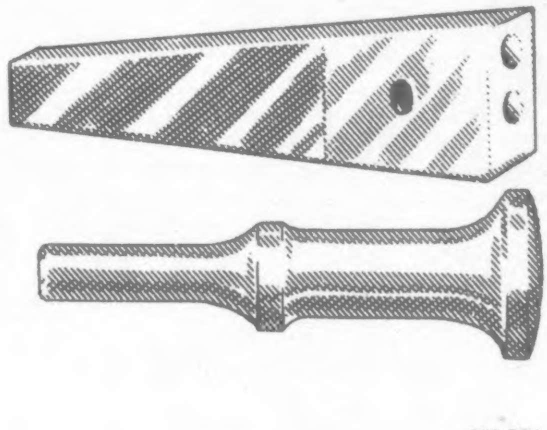
A rivet set is a tool equipped with a die for driving a particular type of rivet. Rivet sets are used in both hand and pneumatic hammer riveting methods. Rivet sets are available to fit every size and shape of rivet head. The ordinary hand set is made of 1/2-inch-diameter carbon steel about 6 inches long and is knurled to prevent slipping in the hand. Only the face of the set is hardened and polished. Sets for the oval head rivets (universal, round, and brazier) are recessed (or cupped) to fit the rivet head. In selecting the correct set, be sure that it will provide the proper clearance between the set and the sides of the rivet head and between the surfaces of the metal and the set. Flush or flat sets are used for countersunk and flathead rivets. In order to set flush rivets properly, the flush sets should be at least 1 inch in diameter.

Special sets, called "draw" sets, are used to "draw up" the sheets being riveted in order to eliminate any opening between them before the rivet is bucked. Each draw set has a hole 1/32 inch larger than the diameter of the rivet shank for which it was made. Sometimes, especially in hand working tools, the draw set and the rivet header are incorporated into one tool. The header part consists of a hole sufficiently shallow for the set to expand the driven rivet "bucktail" and form a head on it when the set is struck by a hammer. Figure 5-2 illustrates a rectangular-shaped hand set which combines the draw and header sets and a flush set used with a pneumatic hammer.

Sets used with pneumatic hammers (rivet guns) are provided in many sizes and shapes to fit the type and location of the rivet. These sets are the same as the hand rivet sets except that the shank is shaped to fit into the rivet gun. The sets are made of high-grade carbon tool steel and are heat treated to provide the necessary strength and wear resistance. The tip or head of the rivet set should be kept smooth and highly polished at all times to prevent marring of rivet heads.

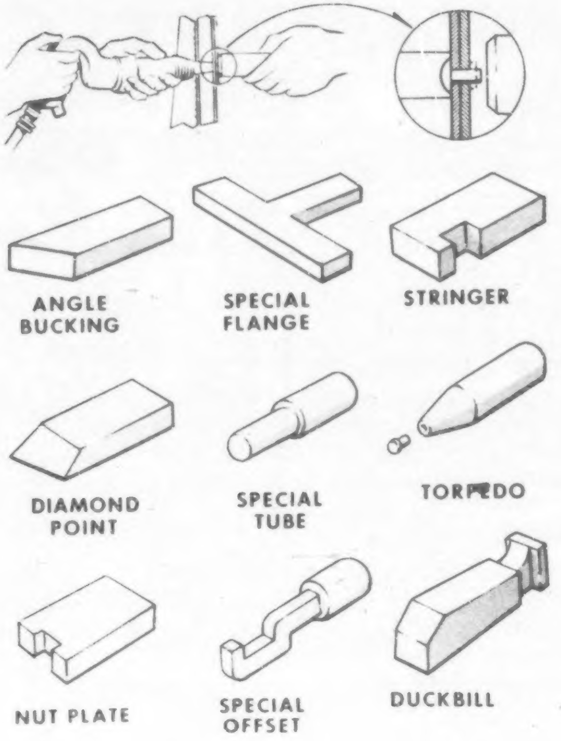
Bucking Bars

Bucking bars are tools used to form bucktails (the head formed during riveting operations) on rivets. They come in many different shapes and sizes, as illustrated in figure 5-3. Bucking bars are normally made from an alloy steel similar to



AM.291

Figure 5-2.–Rivet sets.



AM.292

Figure 5-3.—Bucking bars.

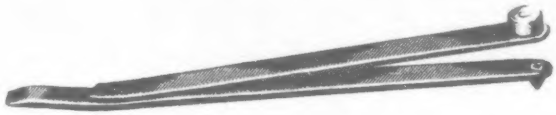
tool steel. The particular shape to be used depends upon the location and accessibility of the rivet to be driven. The size and weight of the bar depend on the size and type of the rivet to be driven. Under certain circumstances, and for specific rivet installations, specially designed bucking bars are manufactured locally. These bars are normally made from tool steel. The portion of the bar designed to come in contact with the rivet has a polished finish. This helps to prevent marring of formed bucktails. Bucking bar faces must be kept smooth and perfectly flat and the edges and corners rounded at all times.

NOTE: Never hold a bucking bar in a vise unless the vise jaws are equipped with protective covers. This will prevent marring of the bucking bar.

A satisfactory rivet installation depends largely on the condition of the bucking bar and the ability of the AMS using it. If possible, hold the bucking bar in such a manner that will allow the longest portion of the bar to be in line with the rivet. The AMS should hold the bucking bar lightly but firmly against the end of the rivet shank so as not to unseat the rivet head. The inertia of this tool provides the force that bucks (upsets) the rivet, forming a flat, head-like bucktail.

Hole Finder

A hole finder is a tool used to transfer existing holes in aircraft structures or skin to replacement skin or patches. The tool has two leaves parallel to each other and fastened together at one end. The bottom leaf of the hole finder has a teat installed near the end of the leaf which is aligned with a bushing on the top leaf, as illustrated in figure 5-4. The desired hole to be transferred is located by fitting the teat on the bottom leaf of the hole finder into the existing rivet hole. The hole in the new part is made by drilling through the bushing on the top leaf. If the hole finder is properly made, holes drilled in this manner will be perfectly aligned. A separate duplicator must be provided for each diameter of rivet to be used.



AM.293

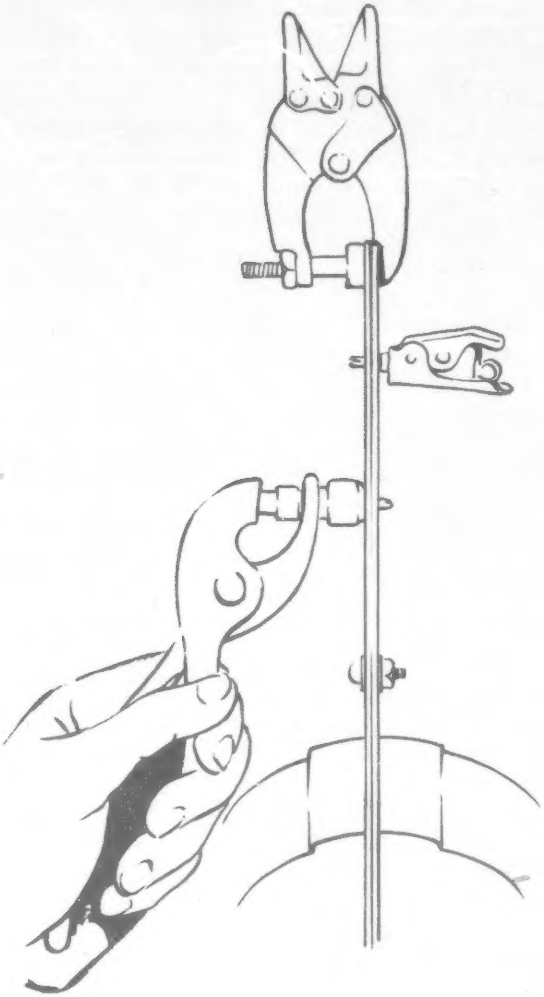
Figure 5-4.—Hole finder.

Skin Fasteners

There are several types of skin fasteners used to temporarily secure parts in position for drilling and riveting and to prevent slipping and creeping of the parts. C-clamps, machine screws, and Cleco fasteners are frequently used in the Navy. (See figure 5-5.) Of the three, the Cleco is the most popular. Cleco fasteners come in sizes ranging from 1/16 to 3/8 inch. The size is normally stamped on the fastener, but may also be recognized by the following color code:

1/16 inch–black
3/32 inch–cadmium
1/8 inch–copper
5/32 inch–black
3/16 inch–brass
1/4 inch–green
3/8 inch–red

The Cleco fastener is installed by compressing the spring with Cleco pliers (forceps). With the spring compressed, the pin of the Cleco is inserted in the drilled hole. The compressed spring is then released, allowing spring tension on the pin of the Cleco to draw the materials together. Clecos should be stored on a U channel plate to protect the pins of the Cleco. Clecos stores at random among heavy tools will become useless due to bent pins.



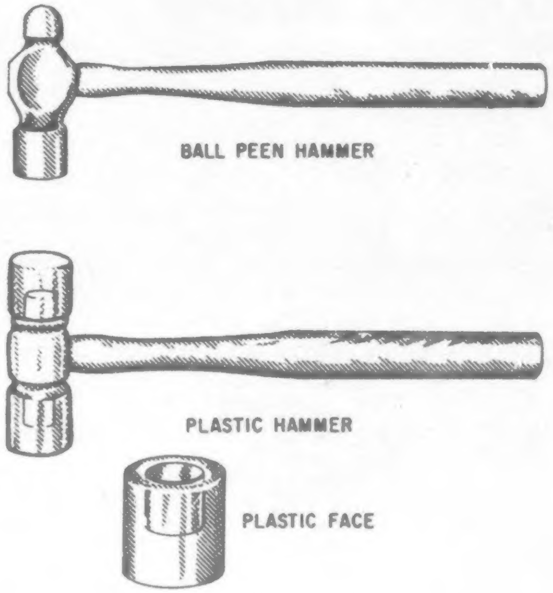
AM.294

Figure 5-5.—Skin fasteners.

STRIKING TOOLS

Generally speaking, this group is composed of various types of hammers, all of which are used to apply a striking force where the force of the hand alone is insufficient. Each of these hammers is composed of a head and a handle, even though these parts differ greatly from hammer to hammer.

The mallet and the ball-peen hammer (fig. 5-6) are of the most concern to the AMS and adequate coverage on their selection, use, care, and safety is contained in Tools and Their Uses, NavPers 10085 (Series), and Airman, NavPers 10307 (Series), and is therefore not repeated here.



AM.23

Figure 5-6.—Striking tools.

CUTTING TOOLS

Included in this group of tools are diagonal cutting pliers, files, hacksaws, twist drills, countersinks, chisels, and the various types of snips used by the AMS to trim or cut material by hand. (See fig. 5-7.)

Adequate coverage on the selection, care, and use of cutting tools is contained in Tools and Their Uses, NavPers 10085 (Series), and Airman, NavPers 10307 (Series), and is therefore not repeated here.

MISCELLANEOUS TOOLS

Miscellaneous tools are tools that do not fall into the category of striking or cutting tools. Some of the miscellaneous tools that are of concern to the AMS are the flashlight, mechanical fingers, inspection mirrors, and steel scales. (See fig. 5-8.)

The Rate Training Manuals, Tools and Their Uses, NavPers 10085 (Series), and Airman, NavPers 10307 (Series), adequately cover the use and care of these tools and is therefore not repeated here.

SPECIAL TOOLS

TORQUE WRENCHES

There are times when, for engineering reasons, a definite pressure must be applied to a nut. In such cases a torque wrench must be used. The three most commonly used torque wrenches are the Deflecting Beam, Dial Indicating, and Micrometer Setting types. (See fig. 5-9.)

Adequate coverage on the selection, care, and use of torque wrenches is contained in Tools and Their Uses, NavPers 10085 (Series), and Airman, NavPers 10307 (Series), and is therefore not repeated here.

SPANNER WRENCHES

Many special nuts are made with notches cut into their outer edge. For these nuts, a hook spanner (fig. 5-10) is required. This is a wrench that has a curved area with a lug on the end. This lug fits into one of the notches of the nut. The spanner may be made for just one particular size notched nut, or it may have a hinged arm to adjust it to a range of sizes.

Pin spanners have a pin in place of a hook, and the pin fits into a hole in the outer part of the nut. Face pin spanners are designed so that the pins fit into holes in the face of the nut.

The AMS uses several different types of spanner wrenches which are manufactured for a specific job. Figure 5-11 shows a special spanner being used on a wheel nut of a main landing wheel.

TENSIOMETER

The tensiometer is an instrument used in checking cable tension. The amount of tension applied in a cable linkage system is controlled by turnbuckles in the system. NOTE: Tension is the amount of pulling force applied to the cable.

A tensiometer is a useful instrument, but is not precision-built. It is inaccurate for cable tension under 30 pounds. All tensiometers in use must be checked for accuracy at least once a month.

One type of tensiometer is shown in figure 5-12. This instrument works on the principle of measuring the amount of force required to deflect a cable a certain distance at right angles to its axis. The cable to be tested is placed under the two blocks on the instrument, and the lever assembly on the side of the instrument is pulled down. Movement of this lever pushes up on the center block, called a riser. The riser pushes the cable at right angles to the two clamping points. The force required to do this is indicated by a pointer on the dial. Different risers are used with different size cables. Each riser carries an identifying number and is easily inserted in the instrument.

Each tensiometer is supplied with a calibration table to convert the dial readings into pounds. One of these calibration tables is illustrated in figure 5-12. For example, in using a No. 2 riser with a 3/16 inch-diameter cable, if the pointer on the dial indicates 48, the actual tension on the cable is 100 pounds. It will be noted that in the case of this particular instrument, the No. 1 riser is used with 1/16-, 3/32-, and 1/8-inch-diameter cables.

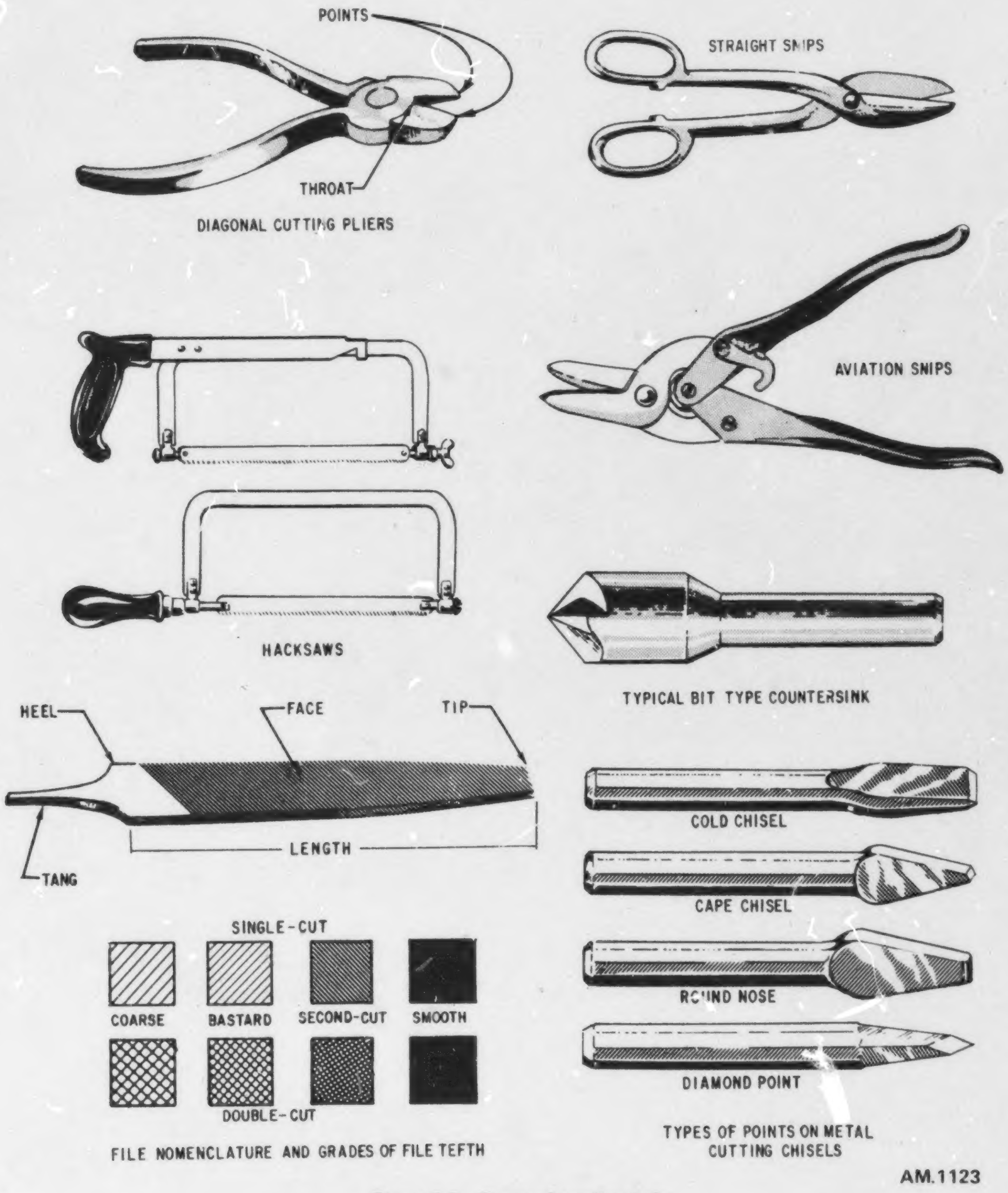
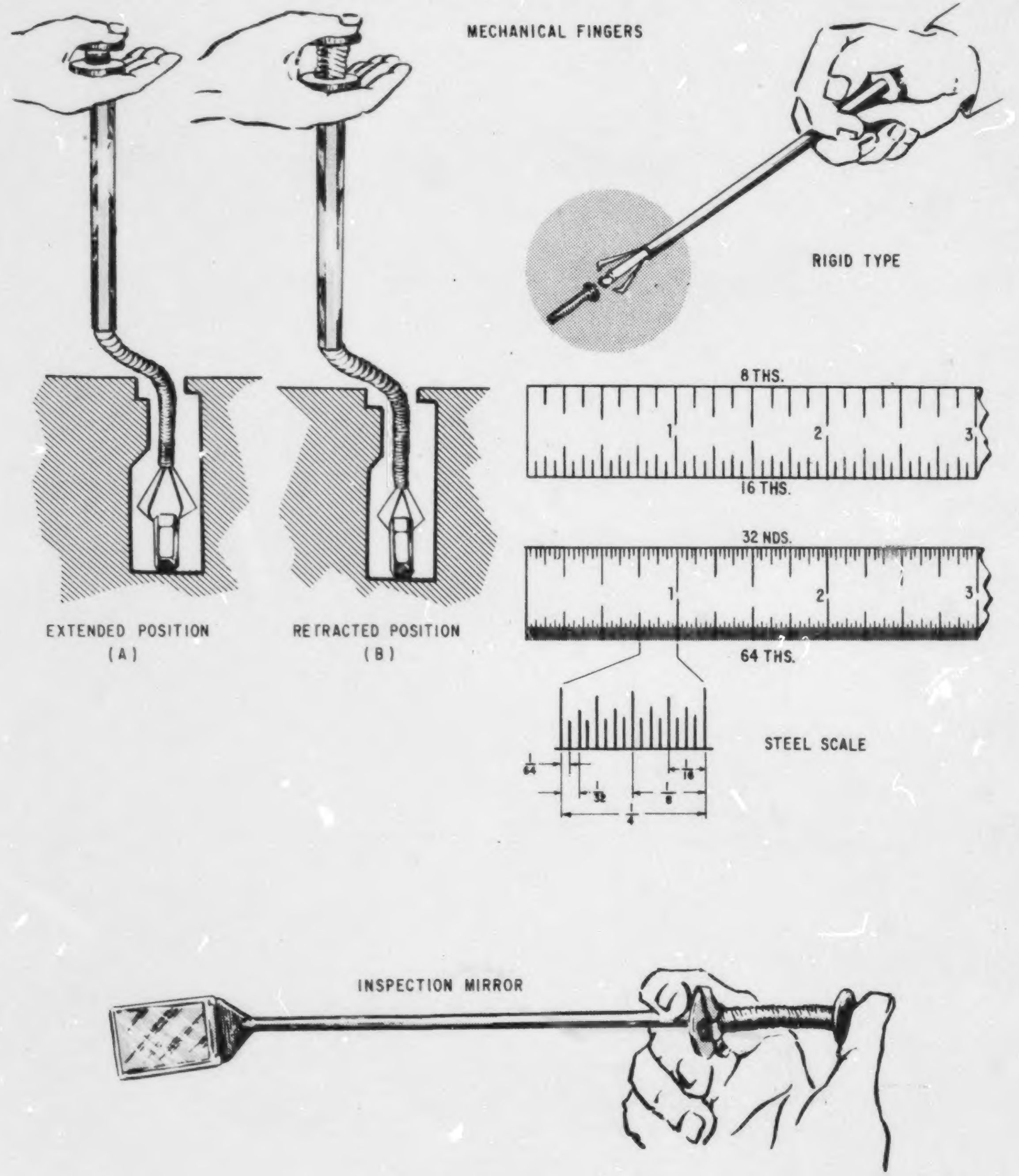
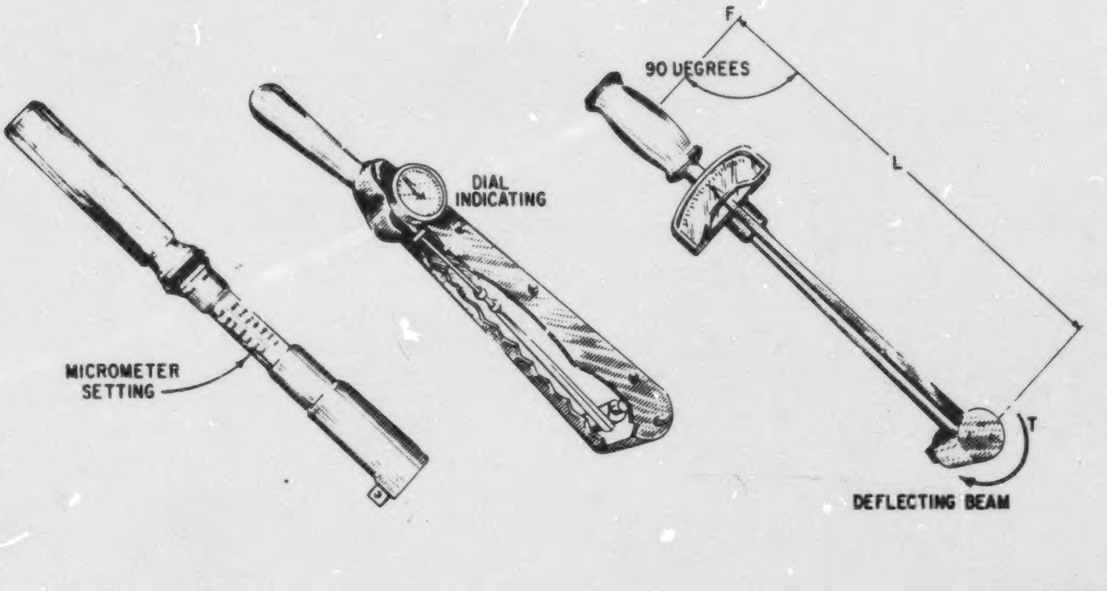


Figure 5-7.—Types of cutting tools.



AM.1126

Figure 5-8.—Miscellaneous tools.



AM.30

Figure 5-9.–Torque wrenches.

CAUTION: The calibration table applies to the particular instrument only and cannot be used with any other. For this reason, the calibration table is secured inside the cover of the box in which the instrument is kept. The chart is serialized with the same serial number as the instrument.

During the adjustment of turnbuckles, the calibration table must be used to obtain the desired tension in a cable. For example, if it is desired to obtain a tension of 110 pounds in a 3/16-inch-diameter cable, the No. 2 riser is inserted in the instrument and the figure opposite 110 pounds is read from the calibration table. In this case, the figure is 52. The turnbuckle is then adjusted until the pointer indicates 52 on the dial. (NOTE: Tensiometer readings should not be taken within 6 inches of any turnbuckle, end fitting, or quick disconnect.)

In some cases, the position of the tensiometer on the cable may be such that the face of the dial cannot be seen by the operator. In such cases, after the lever has been set and the pointer moved on the dial, the brake lever rod on the top of the instrument is moved to the closed position which locks the pointer in place. Then, the lever assembly is released and the instrument removed from the cable with the pointer locked in position. After the reading has been taken, the brake lever rod is moved to the open position, and the pointer will return to zero.

The tensiometer, like any other measuring instrument, is a delicate piece of equipment and should be handled carefully. Tensiometers should never be stored in a toolbox.

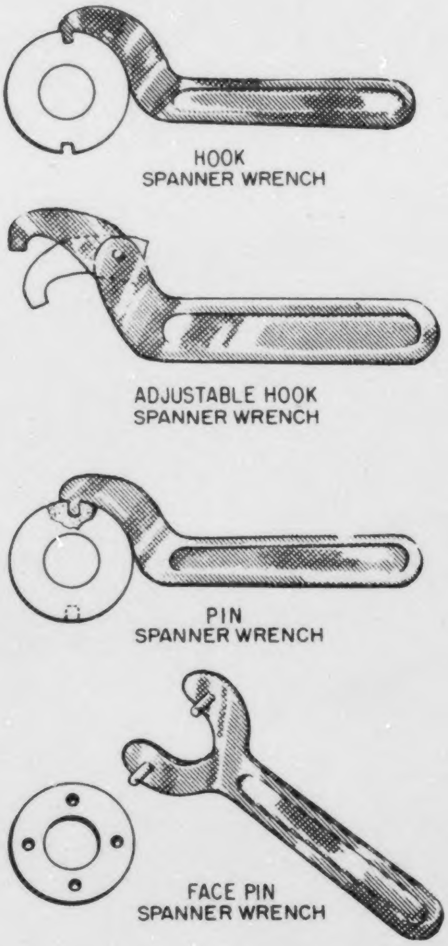
Temperature changes must be considered in cable type systems since this will affect cable tensions. When a temperature is encountered that is lower than that at which the aircraft was rigged, the cables become slack because the aircraft structure contracts more than the cables. When temperatures higher than that at which the aircraft was rigged are encountered, the aircraft structure expands more than the cables and the cable tension is increased.

The cables in any cable linkage system are rigged in accordance with a temperature chart which is contained in the applicable Maintenance Instructions Manual. This chart will give the proper tensions for the various temperature changes above and below the temperature at which the system was rigged.

RIVET HEAD SHAVER

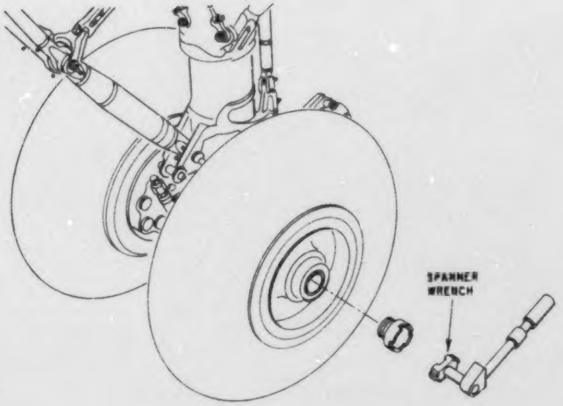
The rivet head shaver shown in figure 5-13 is used by the AMS to smooth countersunk rivet heads that protrude slightly but are still within specified limits. The rivet head shaver is also called a Micro Miller. The depth of cut adjustment can be made in increments of 0.0005 inch on the model shown in figure 5-13. On some models the depth of cut adjustment can be made in increments of 0.0008 inch. The operator can change cutters and adjust their depth without the use of special tools. Once the depth is set, the positive action of the serrated adjustment locking collar prevents accidental loss of setting.

The AMS should position the cutters directly over the rivet head, holding the tool at an angle of 90 degrees to the surface being smoothed. With the tool turning maximum rpm, it is then pressed in towards the surface, maintaining the 90-degree angle. The pressure feet will then be compressed until they bottom out. At this time, assuming the rivet head shaver is adjusted correctly prior to the shaving operation, the rivet head will be shaved aerodynamically smooth.



AM.31

Figure 5-10.—General-purpose spanner wrenches.

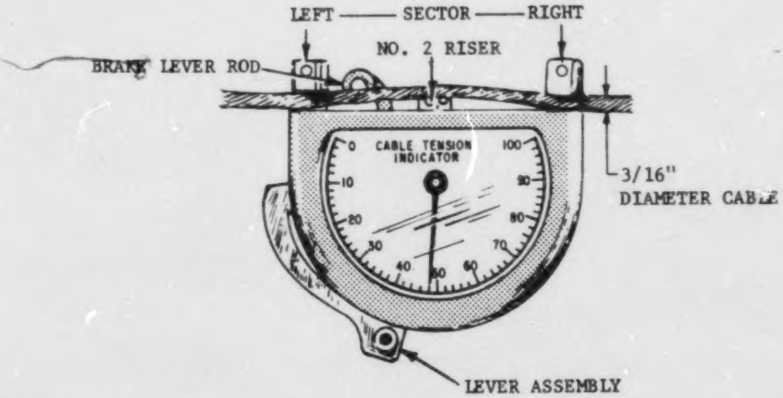


AM.304

Figure 5-11.—Using a special spanner wrench on a wheel nut of a main landing wheel.

PNEUMATIC RIVETERS

Rivet guns vary in size and shape and have a variety of handles and grips, ranging from the offset type to the pistol grip type. Nearly all riveting is done with pneumatic riveters. The pneumatic riveting guns operate on compressed air supplied from a compressor or storage tank.

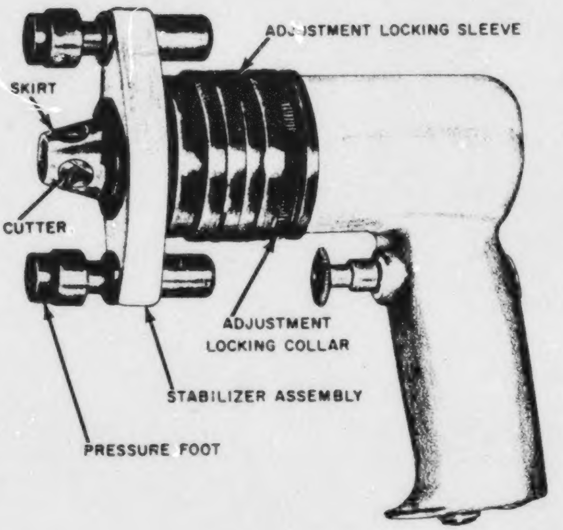


No. 1				Riser	No. 2		No. 3	
DIA	1/16	3/32	1/8	Tension Lbs.	5/32	3/16	7/32	1/4
	14	15	21	30	14	20		
	18	22	27	40	18	25		
	23	27	33	50	22	29		
	27	32	39	60	26	33		
	31	37	44	70	29	37		
	35	41	49	80	32	41		
	39	45	54	90	35	45		
	43	49	59	100	38	48		
	46	53	63	110	41	52		
	49	57	67	120	44	55		
	53	61	71	130	47	58		
	56	65	75	140	49	61		
	59	68	79	150	51	64		
	62	71	82	160	54	67		
	65	74	86	170	56	70		
	68	77	90	180	58	72		
	70	80	93	190	60	74		
	72	83	96	200	62	76		
Typed figures are instrument scale reading corresponding to tension				220	66	81		
				240	70	85		
				260	74	89		
Instrument No. 6659 Model 401-1C-2				280	78	93		
				300	80	97		

AM.33

Figure 5-12.–Cable tensiometer and chart.

Normally, rivet guns are equipped with an air regulator on the handle to control the amount of air entering the gun. Regulated air entering the gun (Fig. 5-14) passes through the handle and throttle valve, which is controlled by the trigger, and into the cylinder in which the piston moves. Air pressure forces the piston down against the rivet set and exhausts itself through side ports. The rivet set recoils, forcing the piston back, and the cycle is repeated. Each time



AM.305

Figure 5-13.—Rivet head shaver.

the piston strikes the rivet set, the force is transmitted to the rivet. Rivet sets come in various sizes and shapes to fit the various shaped rivet heads.

Several types of pneumatic riveters are in general use. Included are the one-shot gun, slow-hitting gun, fast-hitting gun, corner riveter, and the squeeze riveter. (See fig. 5-15.) The type of gun used depends on the particular job at hand, each type having its advantages for certain types of work. Small parts can be riveted by one man if the part is accessible for both bucking and driving, provided the work is properly secured. The greater part of riveted work, however, requires two men.

One-Shot Gun

The one-shot gun is designed to drive the rivet with just one blow. It is larger and heavier than other types and is generally used for heavy riveting. Each time the trigger is depressed the gun strikes one blow. It is rather difficult to control on light-gage metals. Under suitable conditions it is the fastest method of riveting.

Slow-Hitting Gun

The slow-hitting gun has a speed of 2,500 bpm (blows per minute). As long as the trigger is held down, the rivet set continues to strike the rivet. This gun is widely used for driving medium-sized rivets. It is easier to control than the one-shot gun.

Fast-Hitting Gun

The fast-hitting gun heads the rivet with a number of relatively lightweight blows. It strikes between 2,500 and 5,000 bpm and is generally used with the softer rivets. Like the slow-hitting gun, it continues to strike the rivet head as long as the trigger is depressed. This gun is sometimes referred to as a vibrator.

Corner Riveter

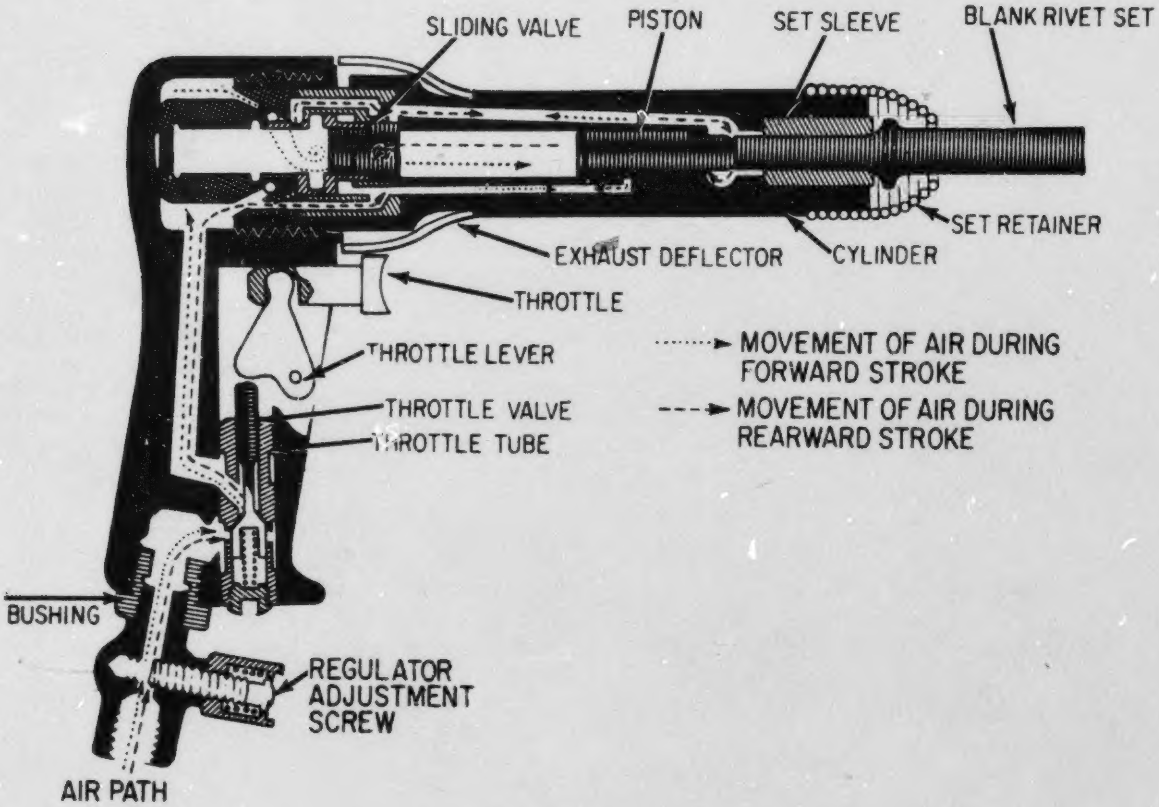
The corner riveter is so named because it can be used in corners and in close quarters where space is restricted. The main difference between this riveter and the other types described lies in the fact that in this type the set is very short and can be used in confined spaces as can be seen in figure 5-15.

Squeeze Riveter

The squeeze riveter differs from the other riveters in that it forms the rivet head by means of squeezing or compressing instead of by distinct blows. Once it is adjusted for a particular type of work, it will form rivet heads of greater uniformity than the riveting guns. It is made both as a portable unit and as a stationary riveting machine. As a portable unit, it is larger than the riveting guns and can be used only for certain types of work that can be accommodated between the jaws. The stationary, or fixed jaw, contains the set and is placed against the rivet head in driving. The rivet squeezer illustrated in figure 5-15 is the pneumatic type.

Rivet Gun Selection

The size and the type of gun used for a particular job depend upon the size of rivets being driven and the accessibility of the rivet.



AM.306

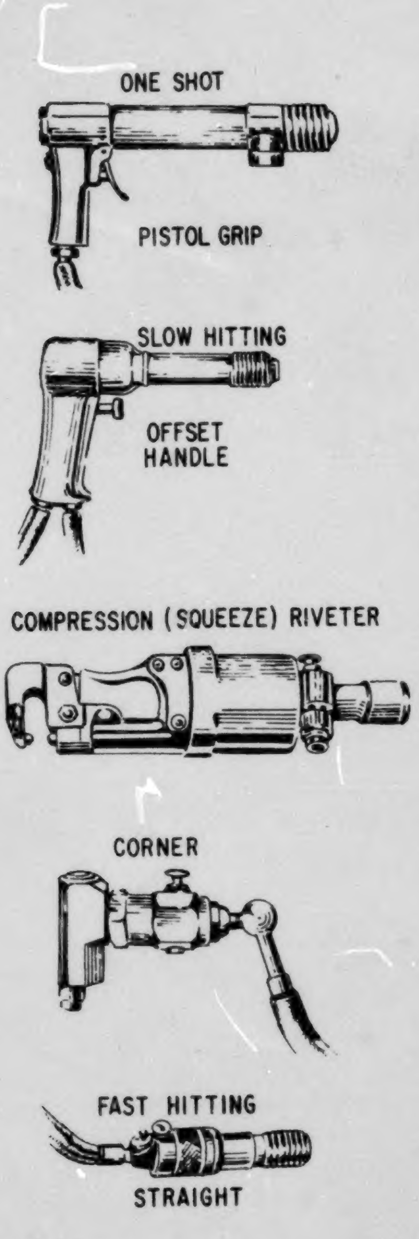
Figure 5-14.–Rivet gun internal airflow.

For driving medium-sized, heat-treated rivets which are in accessible places, the slow-hitting gun is preferred. For small, soft alloy rivets, the fast-hitting gun is preferable. There will be places where a conventional type gun cannot be used. For this type of work, a corner gun is employed.

The larger the rivet, the greater the air pressure that is required. Air pressure reaches the gun through a long, flexible hose. Approximate air pressures for four of the most common rivet sizes are given in table 5-1. Conditions may vary slightly with different alloys.

Table 5-1.–Approximate air pressures for rivet guns.

Rivet size	Air pressure psi
3/32	35
1/8	40
5/32	60
3/16	90



AM.307

Figure 5-15.—Various types of rivet guns.

TAPS AND DIES

Taps and dies are used to cut threads in metal, plastic, or hard rubber. The taps are used for cutting internal threads, and the dies are used to cut external threads. Taps and dies usually come in complete sets, containing tap wrenches, die stocks, guides, and the necessary screw-drivers and wrenches to loosen and tighten adjusting screws and bolts.

Taps and dies should be kept clean and well oiled when not in use. Store them so that they do not contact each other or other tools. Tools and Their Uses, NavPers 10085 (Series), describes and illustrates the principles involved in the selection of the proper taps and/or dies for different types of work.

SCREW AND BOLT EXTRACTORS

Screw and bolt extractors are used to remove broken screws and bolts without damaging the surrounding materials or the threaded hole.

The straight flute type extractors are available in sizes to remove broken or damaged screws having 1/4 to 1/2 inch outside diameter.

Spiral tapered extractors are sized to remove screws and bolts from 3/16 inch to 2 1/8 inches outside diameter.

Most sets of extractors include twist drills and a drill guide. Tools and Their Uses, NavPers 10085 (Series), illustrates and outlines the procedures to use in removing screws and bolts that have been damaged or broken.

STRAP WRENCH

The strap wrench is used during assembly and disassembly of cylinder type components. The strap wrench (fig. 5-16) has a metal body with a webbed strap attached. To use this wrench, the webbed strap is placed around the cylinder and passed through the slot in the metal body. As the mechanic turns the wrench in the desired direction, the webbed strap tightens around the cylinder. This gripping action of the strap causes the cylinder to turn. With the end cap held stationary, the cylinder will be tightened or loosened, depending upon the direction the mechanic turns the wrench. The main advantage of this type of wrench, if used properly, is that it will not mar or damage the cylinder.

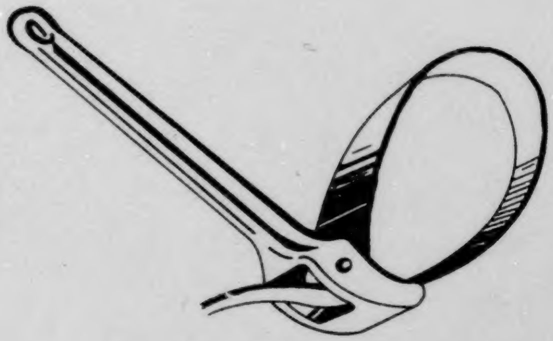


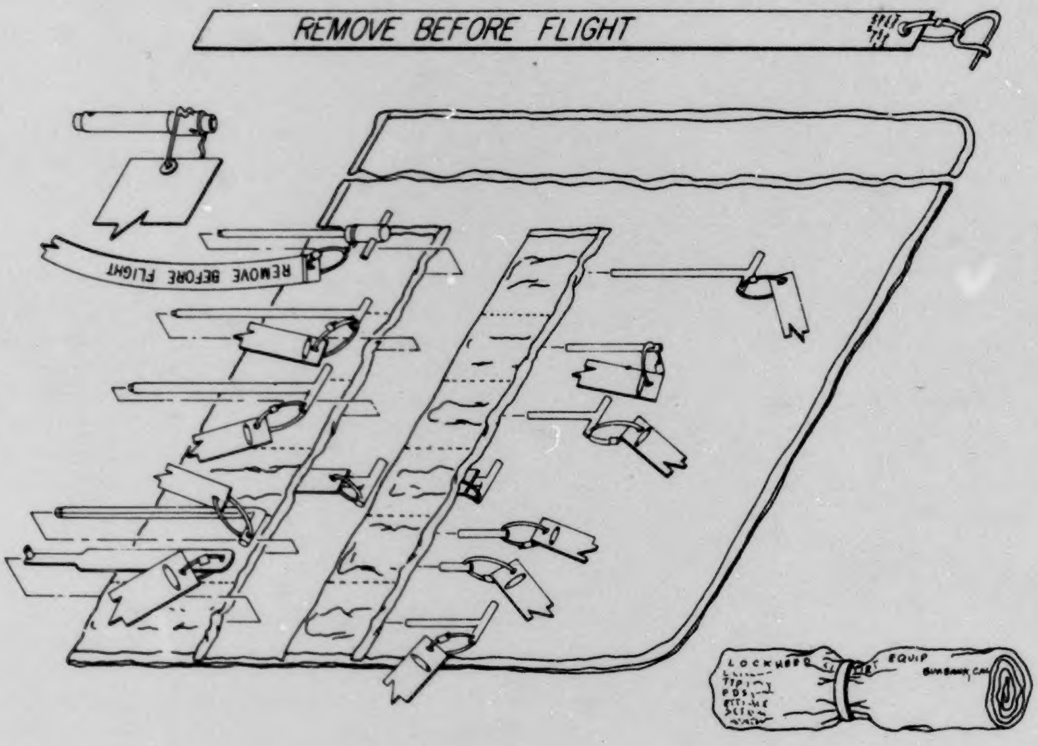
Figure 5-16.–Strap wrench. AM.308

RIG PINS

Rig pins are used by the AMS in rigging control systems. Figure 5-17 shows a rigging pin kit used on one of the Navy's aircraft. As can be seen by this kit, rig pins may come in various sizes and shapes and may be designed for one or many installations. The AMS should refer to the specific Maintenance Instructions Manual for use and selection of rig pins. Rigging of controls and use of rig pins are discussed in chapter 8 of this manual.

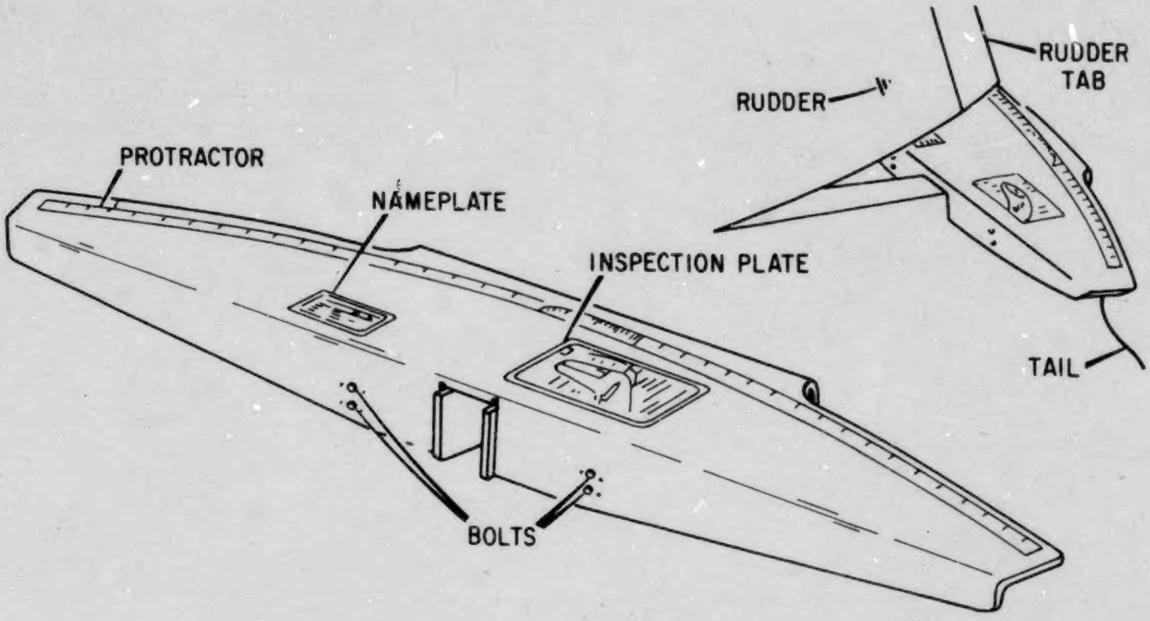
THROW BOARDS

Throw boards are special equipment used on specific aircraft for accurate measurement of control surface travel. (See fig. 5-18.) Each



AM.309

Figure 5-17.–Rigging pin kit.



AM.310

Figure 5-18.—Typical throw board used for rigging rudder and rudder tab controls.

throw board has a protractor type scale which indicates a range of travel in degrees. Zero degree normally indicates the neutral position of the control surface. When the throw board is mounted in place and the control column/stick is in neutral, the trailing edge of the control surface should be aligned on zero. As the control column/stick is moved to its extreme limits, the AMS reads the corresponding degree indication on the throw board. If the travel of the control surface is out of limits, the AMS should adjust cables, push-pull rods, control limit stops, etc., as necessary, to obtain the correct control surface travel. When inspecting and rigging control surfaces, the specific Maintenance Instructions Manual should be consulted. The use of throw boards is discussed further in chapter 8.

CUTTING SHEET METAL

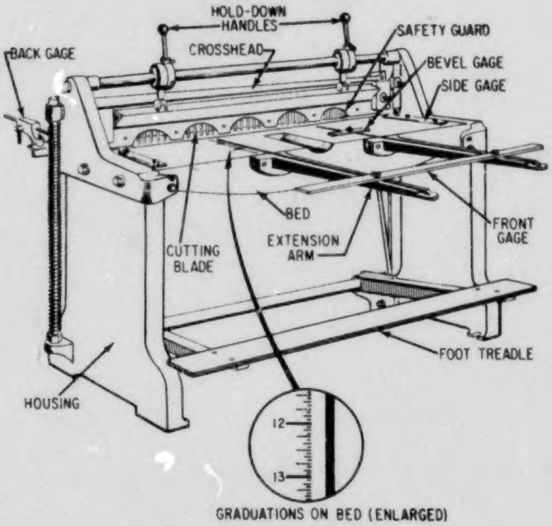
Cutting of sheet metal is a common occurrence for the AMS. Once a project has been laid out on the metal, the next step is to cut it out. The type of cutting equipment to be used depends primarily upon the type and thickness of the material. Another consideration is the size and number of pieces to be cut. A few fairly thin pieces of comparatively soft metal may be more readily turned out by hand-trimming methods. But for harder metals, faster output, and generally more workmanship results, machines designed for metal cutting purposes are used.

CUTTING EQUIPMENT

Machines used in cutting sheet metal may be divided into two groups—manually operated and power operated. Each type of cutting machine has a definite cutting capacity which should never be exceeded. A few of the more common types that are available to the AMS are described in this section.

Squaring Shears

Squaring shears (fig. 5-19) are used for cutting and squaring sheet metal. They may be foot operated or power operated. Squaring shears consist of a stationary blade attached to a bed, and a movable blade attached to a crosshead. To make a cut, the work is placed in the desired position on the bed of the machine and the blade is moved through its downward stroke. The stroke of the cutter blade is always identical in its relation to the bed. Foot-powered squaring shears are equipped with a spring which raises the blade when foot pressure is taken off the treadle. A scale graduated in fractions of an inch is scribed on the bed. Two side guides, consisting of thick steel bars, are fixed to the bed, one on the left and one on the right. Each is placed so that its inboard edge creates a right angle with the cutting edge of the bed. These bars are used to align the metal when absolutely square corners are desired. When cuts other than right angles are to be made across the width of a piece of metal, the beginning and ending points of the cut must be determined and marked in advance. Then the work is carefully placed into position on the bed–the beginning and ending marks on the cutting edge of the bed, and the cut made.



AM.261

Figure 5-19.—Squaring shears.

A holddown mechanism positioned by holddown handles (fig. 5-19) is incorporated in front of the movable cutting edge in the crosshead. Its purpose is to clamp the work firmly in place while the cut is being made. The clamp is quickly and easily made–the operator merely rotates the handle toward himself and the holddown lowers into place. A firm downward pressure on the handle at this time should rotate the mechanism over center on its eccentric cam and lock the holddown in place. Reverse the action to release the work.

Three distinctly different operations–cutting to a line, squaring, and multiple cutting to a specific size–may be accomplished on the squaring shears. When cutting to a line, proceed as above–place the beginning and ending marks on the cutting edge and make the cut. Squaring requires a sequence of several steps. First, square one end of the sheet with one side. Then square the remaining edges, holding one squared end of the sheet against the side guide and making the cut, one edge at a time, until all edges have been squared.

When several pieces are to be cut to the same dimensions, make use of the adjustable gage stop with which most squaring shears are equipped. This stop is located behind the bed cutting edge, and its purpose is to limit the amount of metal that can be slipped between the cutting edges of the blade and bed. The supporting rods for the stop gage are graduated in inches and fractions of an inch, and the gage bar is rigged so that it may be set and fixed at any point on the rods. With the gage set at the desired distance from the cutting blade, push each piece to be cut against the stop. It is then possible to cut all pieces to the same dimensions without measuring and marking each one separately. (NOTE: Physically measure the first piece in such a series to make sure that the stop is accurately set.)

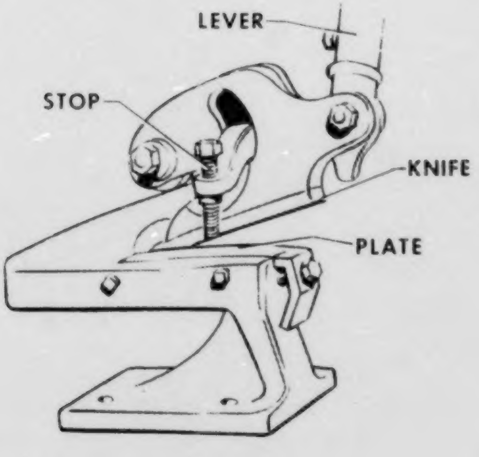
Throatless Shears

Throatless shears (fig. 5-20) are constructed so that sheets of any length may be cut and the metal turned in any direction during the cutting operation. Thus, irregular lines can be followed, or notches made without distorting the metal.

This type of throatless shears is essentially an adaptation of heavy handshears or snips in which the handles are removed, one blade secured to a base, and a long lever attached to the tip of the movable blade. The heavy duty throatless shears are capable of cutting stainless steel up to 0.083 inch in thickness.

Hand Bench Shears

The hand bench shears are similar in operation to a papercutter. They have one fixed blade and a movable blade, hinged at the back, similar to the throatless shears except that the blades are straight and, therefore, used only for straight cutting. Some bench shears have a punching attachment on the end of the frame opposite the shearing blades. This attachment is for punching holes in metal sheets.



AM.262

Figure 5-20.—Throatless shears.

For cutting stock that is narrower in width than the length of the blades, the lever of the shears can be pulled all the way down. When cutting larger pieces, a continuous series of short bites should be made, since complete closing of the blade tends to tear the sheet at the end of each cut.

Unishear

Unishear is a trade name for a type of portable power shears, used for cutting curves and notches as well as straight-line cutting.

This tool might be called a power-operated, combination snips. It has two short blades. The lower blade is held in a fixed position. The upper blade moves up and down in short strokes at a high rate of speed. Its chewing motion is the basis for the widely used nickname of this power tool—"nibblers." The tool will cut metal up to its rated capacity which should never be exceeded. Figure 5-21 illustrates an 18-gage unishear.

The cutting blades are easily removed for sharpening and replacement. The machine will cut as fast as it can be fed up to 15 feet per minute. This is a ruggedly constructed machine; and for satisfactory performance, the best of care is necessary. It should be kept cleaned and oiled at all times.

Hand-Operated Turret Punch

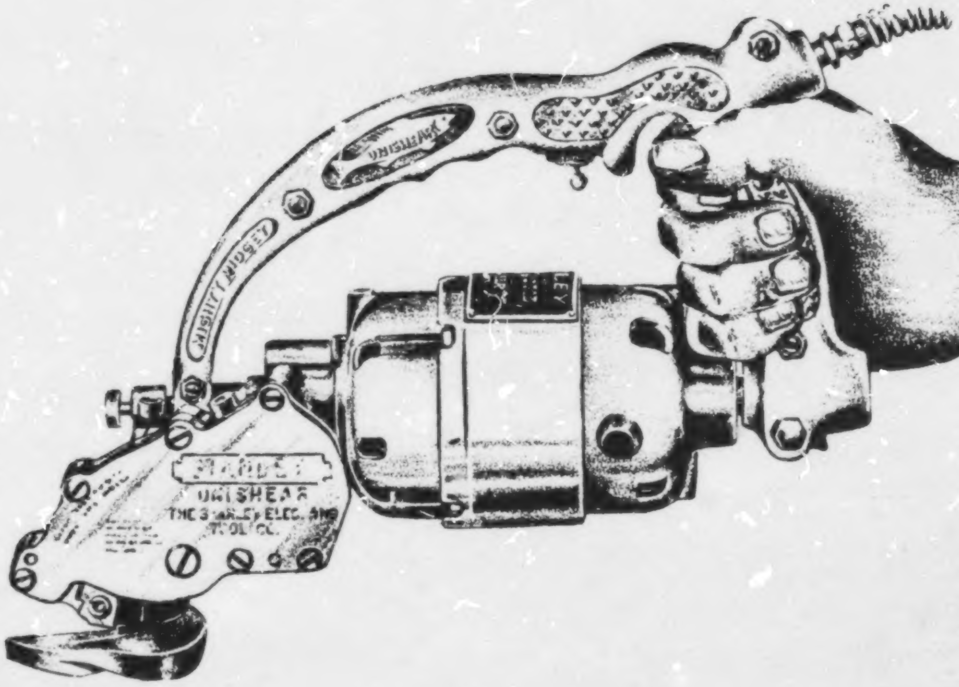
A hand-operated turret punch is shown in figure 5-22. Twelve mated punches and dies are mounted in a rotating turret. Each die block has the size of hole it will punch, as well as the thickness of the material it will accommodate, stamped on the front. These capacities are for mild steel, and this must be kept in mind when punching stainless steel or other alloys.

The operation of the turret punch is simple: release the locking handle on the side of the punch frame, rotate the turret until the desired punch set is lined up with the actuating mechanism (ram), then lock the turret into position. Punch the hole by pulling the operating lever toward the operator, which actuates the ram and punch.

MACHINE FORMING OF SHEET METAL

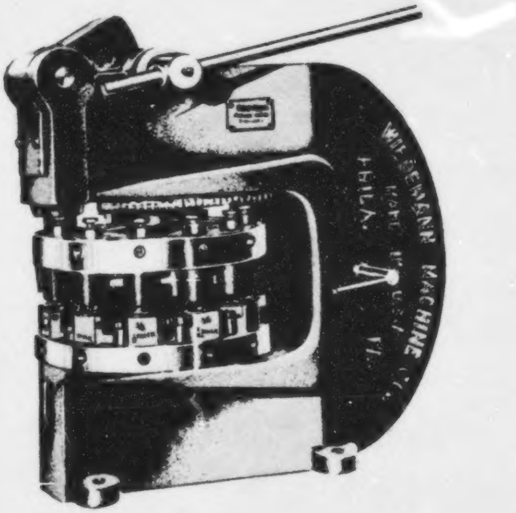
SLIP-ROLL FORMING MACHINE

Sheet metal can be formed into curved shapes over a pipe or a mandrel, but the slip-roll forming machine (fig. 5-23) is much easier to use and produces more accurate bends. Rolling



AM.263

Figure 5-21.—18-gage unishear.



AM.264

Figure 5-22.—Hand-operated turret punch.

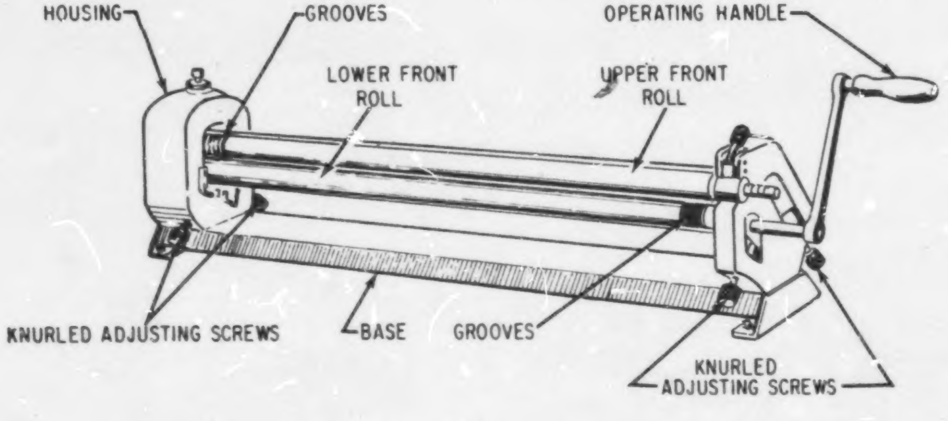
machines are available in various sizes and capacities; some are hand operated, like the one shown in figure 5-23, and others are power operated.

The machine shown in the illustration has two rollers in the front and one roller at the rear. Adjusting screws on each end of the machine control the distance between the front rolls. By varying the adjustments, the machine can be used to form cylinders, cones, and other curved shapes. The front rolls grip the metal and pull it into the machine; therefore, the adjustment of distance between the two front rolls is made on the basis of the thickness of the sheet being worked.

To form a cylinder in the machine (fig. 5-24), follow this procedure:

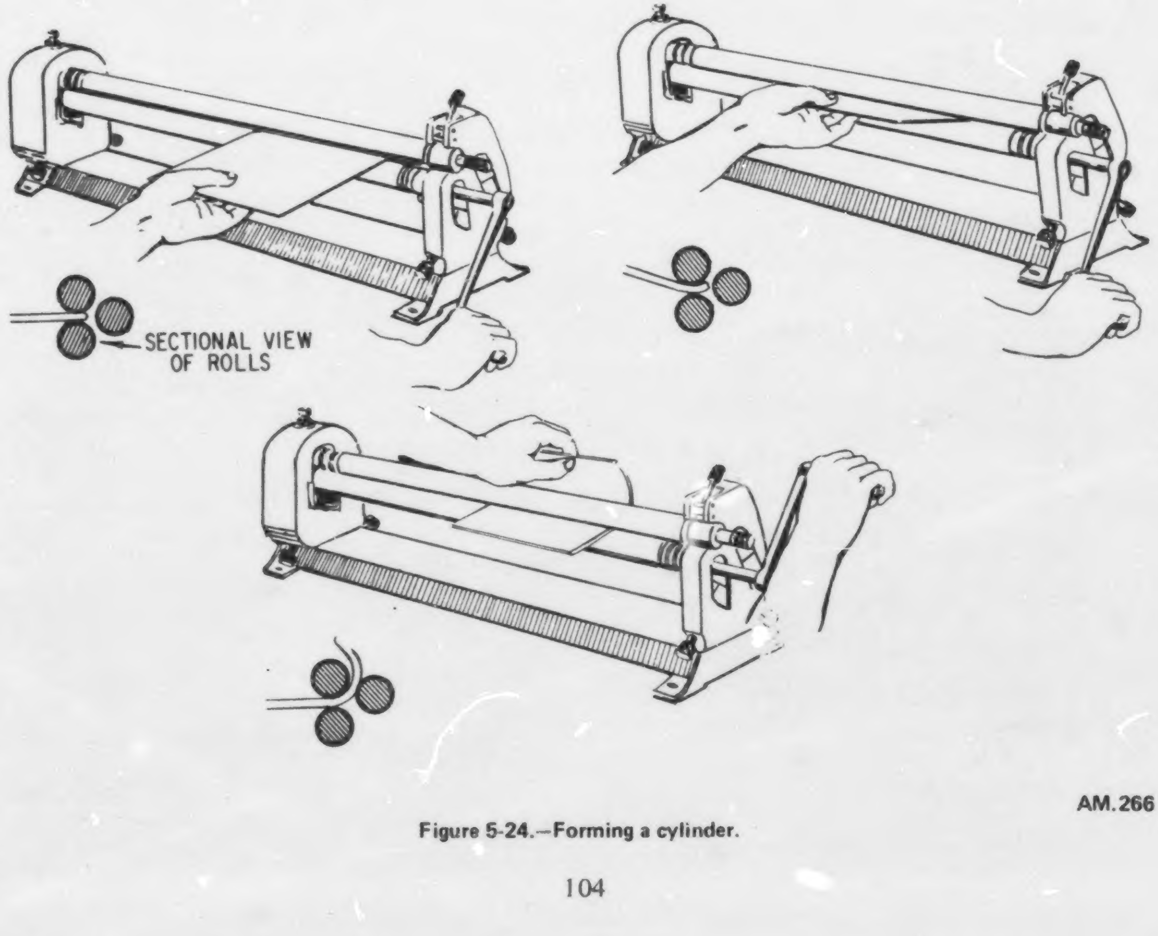
1. Adjust the front rolls so that they will grip the sheet properly.

2. Adjust the rear roll to height that is less than enough to form the desired radius of the cylinder.



AM.265

Figure 5-23.—Slip-roll forming machine.



AM.266

Figure 5-24.—Forming a cylinder.

3. Check to be sure that all three rolls are parallel. (Same space exists between any two rollers at each end of the rollers.)

4. Start the sheet into the space between the two front rolls. As soon as the front rolls have gripped the sheet, raise the free end of the sheet slightly.

5. Pass the entire sheet through the rolls. This forms part of the curve required for the cylinder.

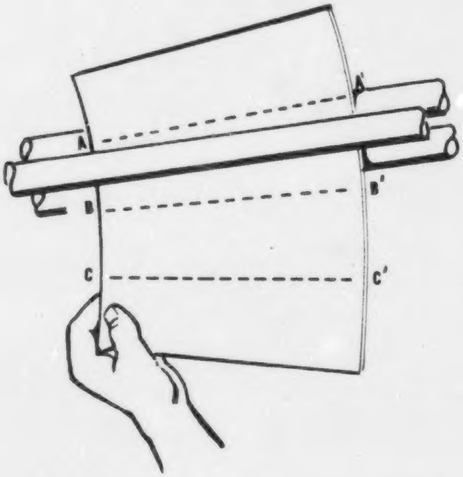
6. Set the rear roll higher to form a shorter radius.

7. Turn the partially formed sheet end over end and again pass it through the rolls.

8. Continue turning the sheet end over end and passing it through the rolls, each time adjusting the rear roll for a new radius, until a truly cylindrical shape has been formed.

9. Remove the cylinder from the machine. The top front roll has a quick-releasing device by which one can release one end of the roll. This allows the released end of the roll to be raised and the newly formed cylinder slipped off just as one would slip a ring from his finger.

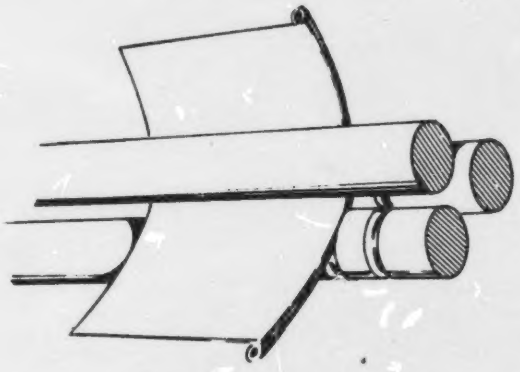
Conical shapes can be formed by setting the back roll at an angle before running the sheet through it, or they can be made with the rolls parallel. (See fig. 5-25.) To make a cone with the rolls parallel, the sheet must be fed through the rolls in such a manner that the element lines (A-A', B-B', etc., in the illustration) pass over the rear roll in a line parallel to the roll. This involves slipping the large end of the cone through the rolls at a slightly faster rate than the small end is being rolled through.



AM.267

Figure 5-25.—Rolling a conical shape.

The grooves at the end of the rolls can be used to form circles of wire or rod; they can also be used to roll wired edges, as shown in figure 5-26.



AM.268

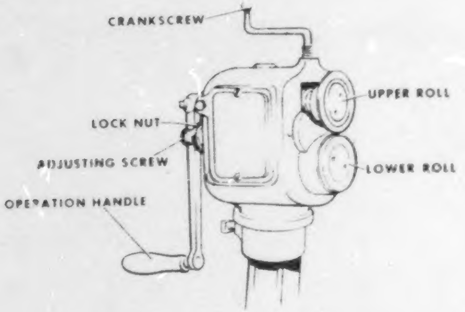
Figure 5-26.—Rolling a wired edge.

ROTARY MACHINE

The rotary machine shown in figure 5-27 is used on cylindrical and flat sheet metal to shape the edge or to form a bead along the edge. Various shaped rolls (some illustrated in fig. 5-28) can be installed on the rotary machine to perform the following operations; beading, turning, wiring, crimping, and burring. These operations are described in the following paragraphs.

Beading Rolls

Beading rolls are used for turning beads (grooves) on such items as tubing, cans, and buckets; and for stiffening and gripping. Beads may also be placed on sheet stock that is to be welded. There are several different types of beading rolls. Those shown in figure 5-28 are the single bead rolls. Whenever beading, the groove should not be made too deeply in a single rotation as this tends to weaken the metal.



AM.269

Figure 5-27.—Rotary machine.

Turning Rolls

Turning rolls are used for turning an edge to receive a stiffening wire. When turning an edge, rest the cylinder to be wired on the lower wheel and press against the gage. The gage is adjusted according to the size of wire to be used. With the work set in place, bring down the upper roll until it grips the metal. Turn the crank slowly, holding the metal so that it will feed into the rolls while continuing to press against the guide. After the first revolution, gradually raise the metal until it touches the outer face of the top roll. Remove the stock by raising the top roll.

Wiring Rolls

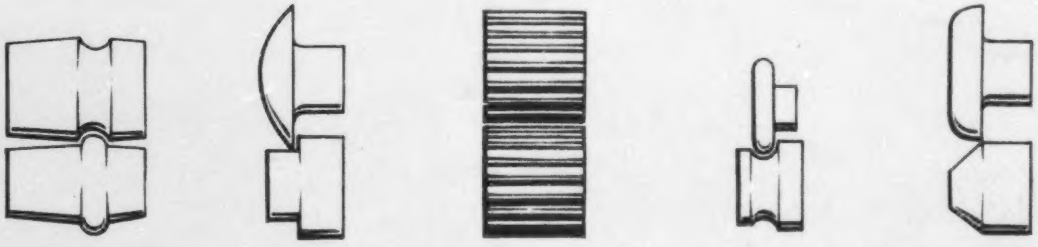
Wiring rolls are used to finish the wired edges prepared in the turning rolls. To use the wiring rolls, adjust the top roll so that it is directly above the point on the lower roll where the beveled and flat surfaces meet, as shown in (A) of figure 5-29. Adjust the guide to the position shown in (B), then bring the top roll down so that it will turn the edge of the metal as shown in (C). Remove the stock from the machine by raising the top roll.

Crimping Rolls

Crimping rolls are used to make one end of a pipe smaller than the other so that two sections may be slipped together, one end into the other. A bead is placed on a pipe first, then it is crimped. The bead forms a shoulder to keep the pipe from slipping too far into the adjoining section.

Burring Rolls

Burring is perhaps the most difficult operation performed on a rotary machine. Before placing the work in the machine, make sure that the cylinder or circular disc to be burred is cut or formed as perfectly round as possible. Then adjust the gage on the machine so that the space between the inside of the upper roll and the gage is set to the width of the burr. Next, place the object between the rolls and against the gage,


SINGLE BEAD ROLLS
BURRING ROLLS
STRAIGHT CRIMPING ROLLS
TURNING ROLLS
WIRING ROLLS

AM.270

Figure 5-28.—Roll dies used on rotary machine.

and lower the upper roll until it scores the material slightly. Now turn the crank slowly, allowing the metal to slide between the thumb and fingers. Apply a slight upward pressure as the metal passes between the rolls. After the first revolution, lower the top roll and again pass the metal between the rolls. Repeat this process, raising the edge slightly with each complete revolution of the material until the edge has been burred to the proper angle.

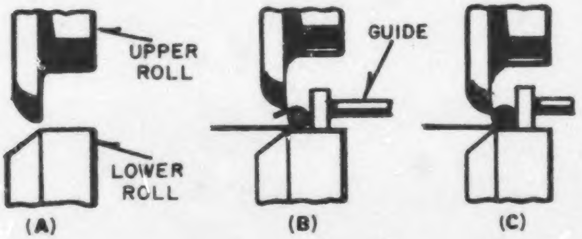


Figure 5-29.—Wiring operation.

BENDING SHEET METAL

Straight-line bends and folds in sheet metal are ordinarily made on the cornice brake and bar folder; however, a considerable amount of bending is also carried out by hand-forming methods. Hand forming may be accomplished by using stakes, blocks of wood, angle iron, a vise, or the edge of a bench.

BENDING OVER STAKES

Stakes are used to back up sheet metal for the forming of many different curves, angles, and seams in sheet metal. Stakes are available in a wide variety of shapes, some of which are shown in figure 5-30. The stakes are held securely in a stake holder or stake plate (also illustrated) which is anchored in a workbench. The stake holder contains a variety of holes to fit a number of different types of shanks.

Although stakes are by no means delicate, they must be handled with reasonable care. They must not be used as backing when chiseling holes or notches in sheet metal, or when performing any other job which might damage the faces of the stakes.

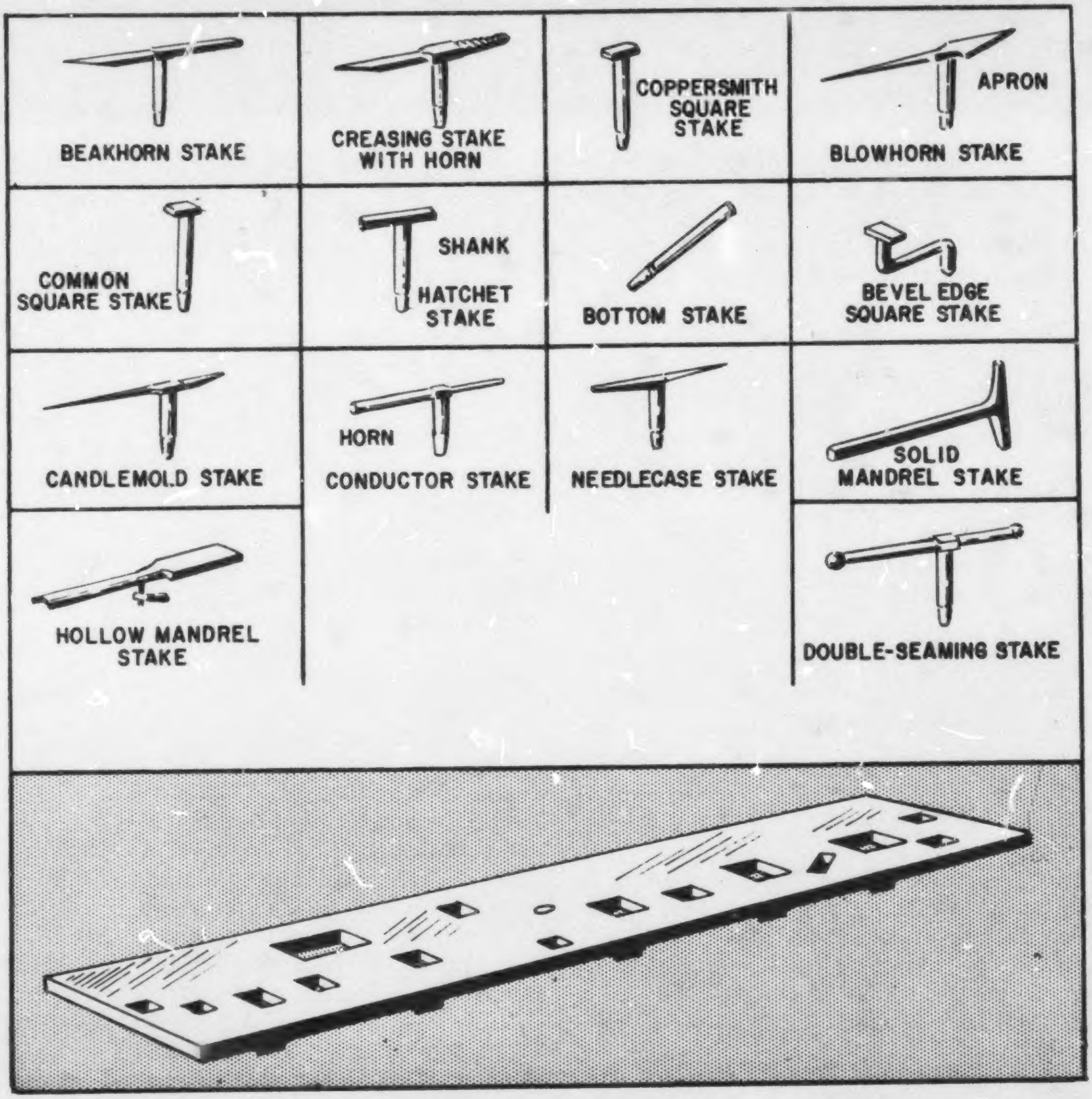
BENDING IN A VISE

Straight-line bends of comparatively short sections can be made by hand with the aid of wooden or metal bending blocks. After the part has been laid out and cut to size, clamp it rigidly along the bend line between two forming blocks held in a vise. The forming blocks usually have one edge rounded to give the desired bend radius. (See fig. 5-31.) By tapping lightly with a rubber, plastic, or rawhide mallet, bend the metal protruding beyond the bending block to the desired angle.

Start tapping at one end, and work back and forth along the edge, making the bend gradually and evenly. Continue this process until the protruding metal is bent to the desired angle. If a large amount of metal extends beyond the bending blocks, maintain enough hand pressure against the protruding sheet to prevent the metal from bouncing. Remove any irregularity in the flange by holding a straight block of hardwood edgewise against the bend and striking it with heavy blows of a hammer or mallet. If the amount of metal protruding beyond the bending blocks is small, make the entire bend by using the hardwood block and hammer.

Curved flanged parts have mold lines that are either concave or convex. The concave flange is formed by stretching, while the convex flange is formed by shrinking. Such parts are shaped with the aid of hardwood or metal form blocks. These blocks are made in pairs and specifically for the shape of the part being formed. Each pair fits exactly and conforms to the actual dimension and contour of the finished article.

Cut the material to be formed to size, allowing about one-quarter inch of excess material for trim. File and smooth the edges of the material to remove all nicks caused by the cutting tools. This reduces the possibility of the material cracking at the edges during the forming operation. Place the material between the form blocks and clamp tightly in a vise so that the material will not move or shift. Clamp the work as closely as possible to the particular area

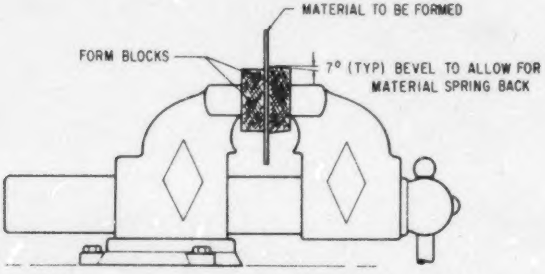


AM.272

Figure 5-30.—Stakes and stake plate.

being formed to prevent strain on the form block and to keep the material from slipping.

Concave surfaces are formed by stretching the material over a form block. (See fig. 5-32.) Using a plastic or rawhide mallet with a smooth, slightly rounded face, start hammering at the extreme ends of the part, and continue toward the center of the bend. This procedure permits some of the material at the ends of the part to be worked into the center of the curve where it will be needed. Continue hammering until the metal is gradually worked down over the entire flange and flush with the form block. After the flange is formed, trim off the excess material and check the part for accuracy.



AM.273

Figure 5-31.–Preparation for straight bend by hand.

Convex surfaces are formed by shrinking the material over a form block. (See fig. 5-33.) Using a wooden or plastic shrinking mallet and a backup or wedge block, start at the center of the curve and work toward both ends. Hammer the flange down over the form, striking the metal with glancing blows at an angle of approximately 45 degrees, and with a motion that will tend to pull the part away from the radius of the form block. While working the metal down over the form block, the wedge block is used to keep the edge of the flange as nearly perpendicular to the form block as possible. The wedge block also lessens the possibility of buckles and of splitting or cracking the metal.

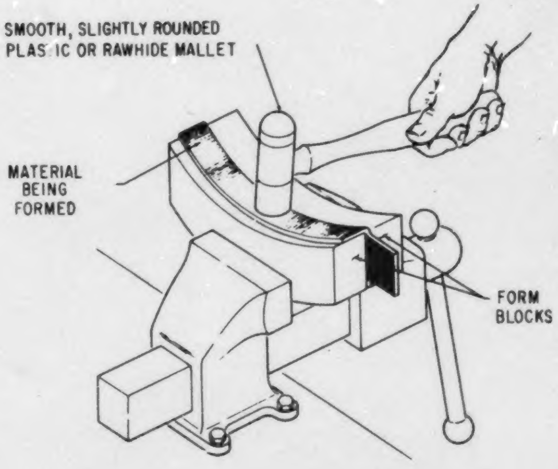
Another method of hand forming convex flanges is by using a lead bar or strap. The material, while secured in the form block, is struck by the lead strap which takes the shape of the part being formed and forces it down against the form block. One advantage in using this method is that the metal is formed without marring or wrinkling and is not thinned out as much as it would be by other methods of hand forming. This method is also illustrated in figure 5-33. After the flange is formed by either method, trim off the excess material and check the part for accuracy.

BENDING ON A BRAKE

The easiest and most accurate method of making straight-line bends on a piece of sheet metal is by the use of a box and pan brake or a cornice brake. The use of these brakes is relatively simple; however, if they are not used correctly, the time and the work involved in computing and laying out of bend allowance, as well as the metal, are wasted. Before bending any work demanding an accurate bend radius and definite leg length, the settings of the brake should be checked with a piece of scrap metal. When making an ordinary bend on a brake, place the sheet to be bent on the bed so that the bend line is directly under the upper jaw or clamping bar, then pull down the clamping bar handle. This brings the clamping bar down to hold the sheet firmly in place. Set the stop for the proper angle or amount of bend, and make the bend by raising the bending leaf until it strikes the stop. If more than one bend is to be made, bring the next bend line under the clamping bar and repeat the bending procedure.

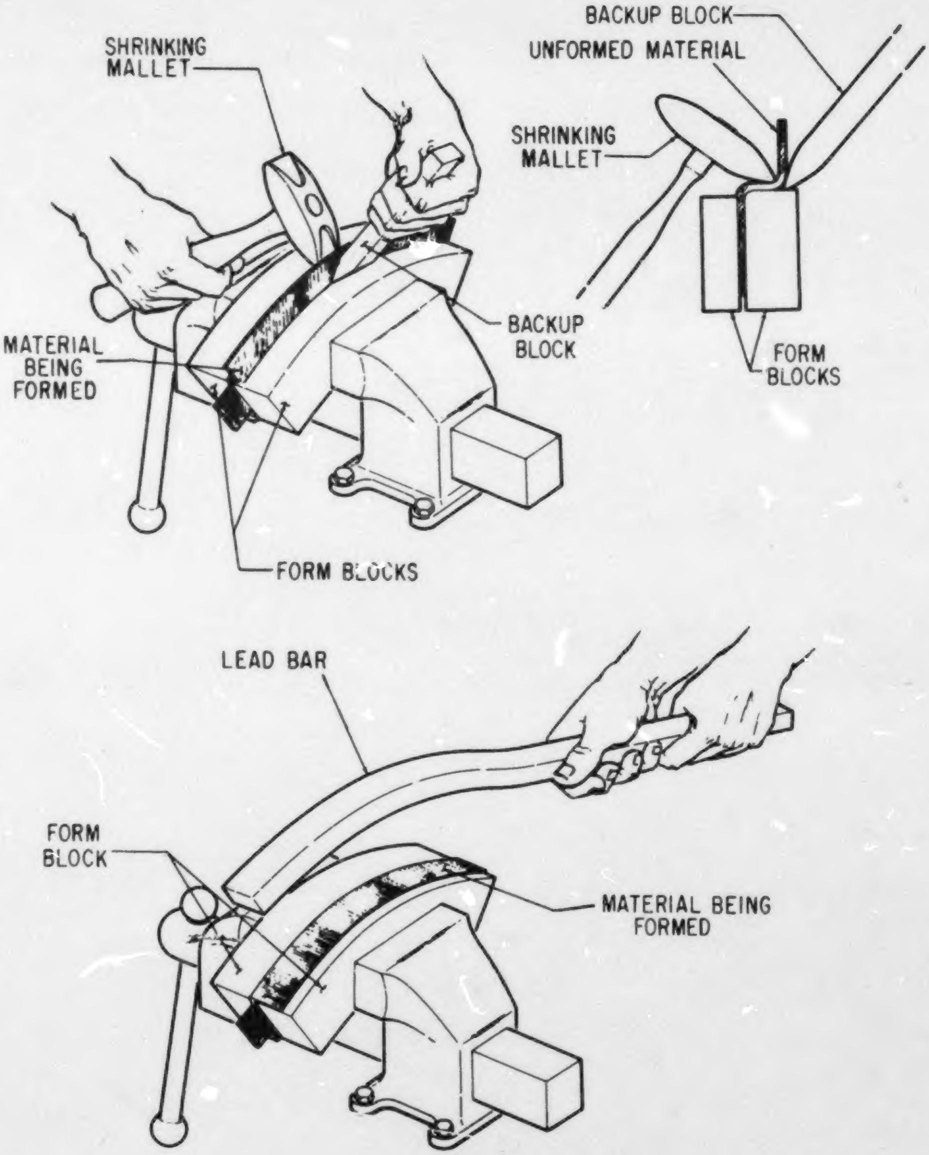
Cornice Brake

The cornice brake (fig. 5-34) is designed for bending large sheets of metal. It is adjustable for


SMOOTH, SLIGHTLY ROUNDED PLASTIC OR RAWHIDE MALLET
MATERIAL BEING FORMED
FORM BLOCKS

AM.274

Figure 5-32.–Forming concave hand bend.



AM.275

Figure 5-33.—Forming convex hand bends.

clamping a wide variety of metal thicknesses and for bending this metal to a variety of radii.

The brake is equipped with a stop gage, consisting of a rod, a yoke, and a setscrew, by means of which the travel of the bending leaf is limited. This is a useful feature when it is desired to make a number of pieces with the same angle of bend.

The standard cornice brake is extremely useful for making single hems, double hems, lock seams, and various other shapes, some of which require the use of molds. The molds are fastened to the bending leaf of the brake by means of friction clamps, in such a position that the work can be formed over them. Figure 5-35 shows sheet that is ready to be formed over a mold attached to a cornice brake.

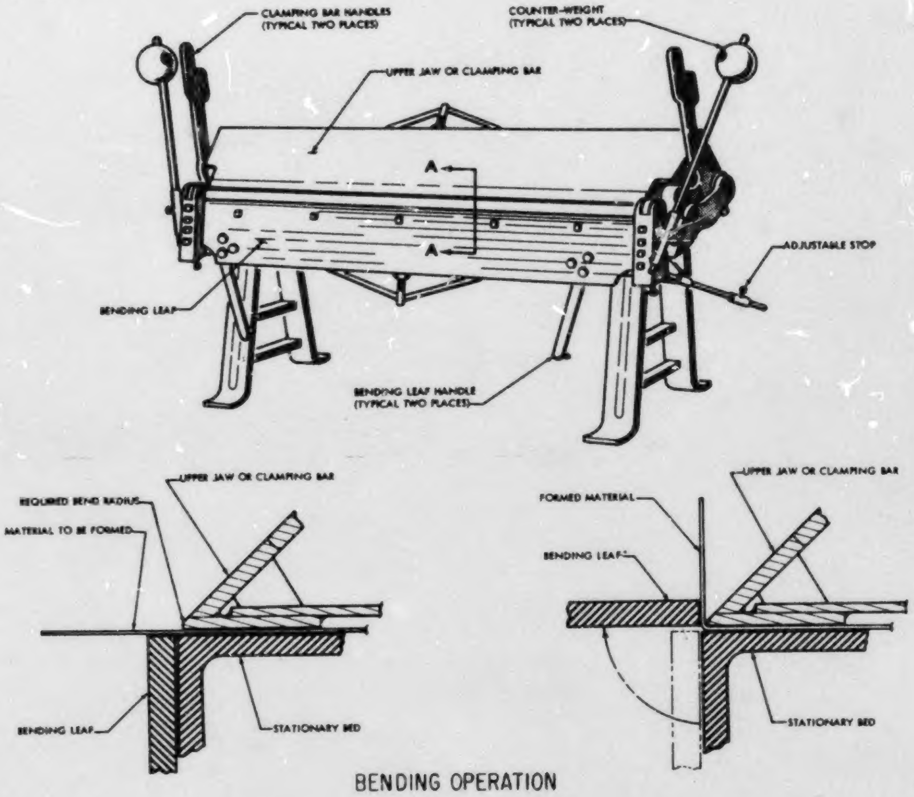
Box and Pan Brake

The box and pan brake (fig. 5-36) is often called the finger brake since it does not have one solid upper jaw as does the cornice brake, but instead is equipped with a series of steel fingers of varying widths. The finger brake can be used to do everything that the cornice brake can do and several things that the cornice brake cannot do.

The finger brake is particularly useful in the forming of boxes, pans, and other similar shapes. If these shapes were formed on a cornice brake, one would have to straighten part of the bend on one side of the box in order to make the last bend. In the finger brake, simply remove the fingers that in the way and use only the fingers required to make the bend.

The fingers are secured to the upper leaf by thumbscrews, as shown in figure 5-37. All fingers which are not removed for any operation must be securely seated and firmly tightened before the brake is used.

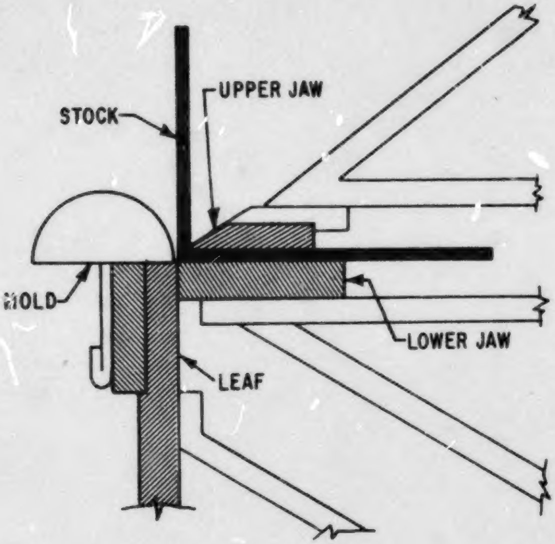
To keep brakes in good condition, keep the working parts well oiled and be sure that the jaws are free of rust and dirt. In operating the brakes, take care to avoid doing anything that would spring the parts, force them out of


CLAMPING BAR HANDLES (TYPICAL TWO PLACES)
COUNTER-WEIGHT (TYPICAL TWO PLACES)
UPPER JAW OR CLAMPING BAR
A
A
ADJUSTABLE STOP
BENDING LEAF
BENDING LEAF HANDLE (TYPICAL TWO PLACES)
UPPER JAW OR CLAMPING BAR
REQUIRED BEND RADIUS
MATERIAL TO BE FORMED
BENDING LEAF
STATIONARY BED
UPPER JAW OR CLAMPING BAR
FORMED MATERIAL
BENDING LEAF
STATIONARY BED
BENDING OPERATION

AM.276

Figure 5-34.—Cornice brake and operation.

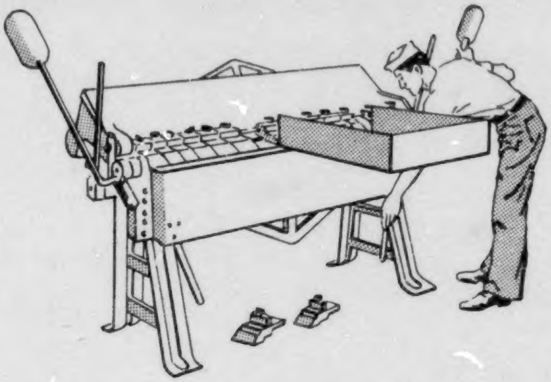
alignment, or otherwise damage them. Never use brakes for bending metal that is beyond their capacity as to thickness, shape, or type. Never try to bend rod, wire, strap iron, or spring steel sheets in a brake. If it is necessary to hammer the work, take it out of the brake first.



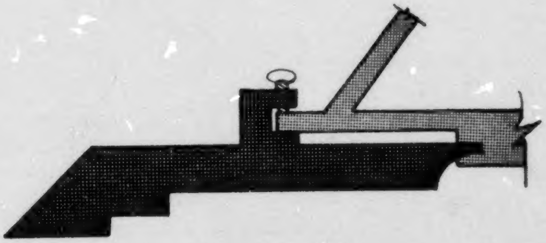
AM.277
Figure 5-35.—Cornice brake with mold and stock.

BENDING ON BAR FOLDER

The bar folder may be used to bend and fold metal in a number of different shapes, as illustrated in figure 5-38. This machine has two adjustments, one for regulating the width of the fold and the other to provide sharp or rounded bends. To operate the bar folder, adjust the thumbscrew to the specified width of the fold, then turn the adjusting knob on the back of the machine for the desired sharpness of the bend. Insert the metal under the folding blade until it rests against the stops. Hold the metal firmly in place with one hand, grasp the handle with the other, and pull forward until the desired fold is made. The necessary steps in making a single hem are illustrated in figure 5-39.



AM.278
Figure 5-36.—Box and pan brake being used to form box.



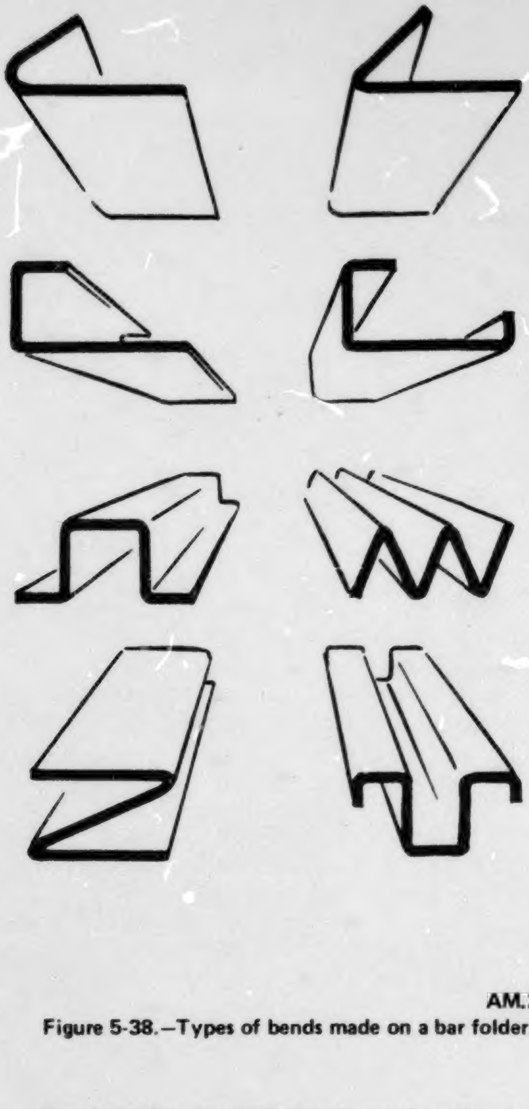
AM.279
Figure 5-37.—Finger secured in box and pan brake.

SHEET METAL EDGES AND SEAMS

REINFORCED EDGES

There are several methods used to reinforce or stiffen the edges of sheet metal. One method is to form either a single or double hem; another is to reinforce the edge with a wire or rod.

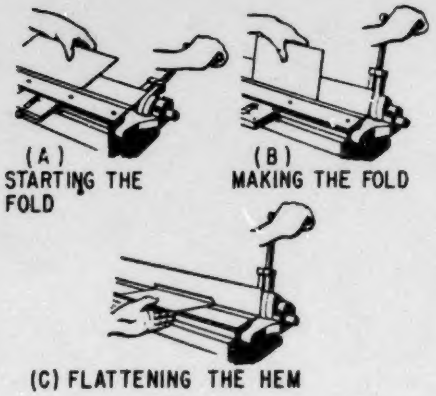
A single hem is formed by simply turning the metal back on itself once, as shown in figure 5-40. A double hem, also shown in the illustration, is formed in the same manner, except that the metal is folded twice instead of once.



AM.280

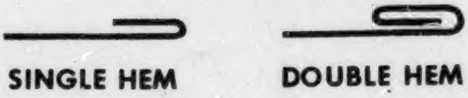
Figure 5-38.–Types of bends made on a bar folder.

A wire edge is made by wrapping the metal around a piece of wire or rod, the metal being bent by hand or on a bar folder. An allowance equal to two and one-half times the diameter of the wire should be provided for the fold to receive the wire. Figure 5-41 shows a wire edge being formed by hand although a much more workmanlike job is accomplished by using the rotary machine illustrated in figure 5-27. The final wrapping operation may be continued either with the peen of a hammer or with a wiring machine.



AM.281

Figure 5-39.–Bar folding a single hem.



AM.282

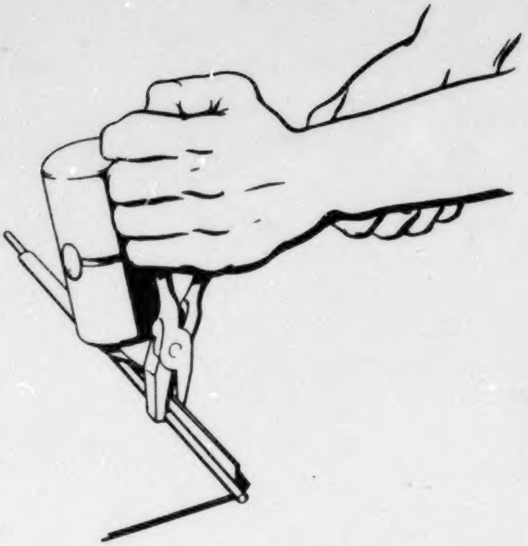
Figure 5-40.–Single and double hems.

SHEET METAL SEAMS

The place where two sheets of metal are joined together is called a seam. The three most common types of seams used in sheet metal work are the lap seam, grooved seam, and the standing seam.

The lap seam is the least difficult to fabricate. In making this seam, the pieces of stock are merely lapped one over the other and secured by riveting or soldering, or both, the method used depending upon the degree of structural strength required and whether or not a watertight seam is required.

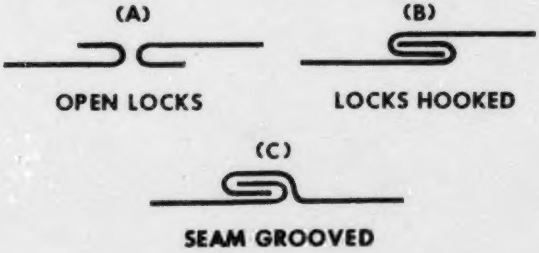
A grooved seam is used in the construction of cylindrical objects, such as funnels, pipe sections, containers, marking buoys, and tanks. The steps in forming a grooved seam are shown in



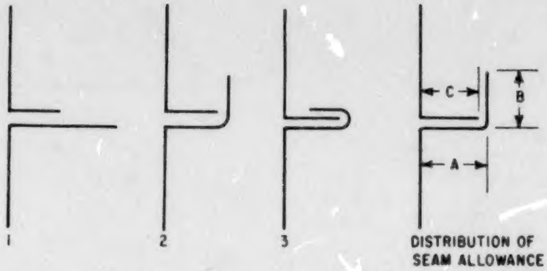
AM.283
Figure 5-41.—Hand forming a wire edge.

figure 5-42. Step (C) is accomplished with either a hand or machine groover.

The standing seam is frequently used when joining two sections or parts of an object, such as the splash ring to the body of a funnel. The steps in making a standing seam are shown in figure 5-43. If the object has straight sides, the flanges may be turned in the bar folder; and if cylindrical, the flanges are turned on the burring machine. Notice the distribution of the allowance for the seam. Two-thirds of it is on one section, the remaining portion of the other. Sections A and B are equal, and C is one thickness of the metal less than A.



AM.284
Figure 5-42.—Forming a grooved seam.



AM.285
Figure 5-43.—Steps in forming a standing seam.

BEND ALLOWANCE

When bending metal to exact dimensions, the amount of material used in forming the bend must be known. The amount of material which is actually used in making the bend is known as BEND ALLOWANCE.

Bending compresses the metal on the inside of the bend and stretches the metal on the outside of the bend. Approximately halfway between these two extremes lies a space that neither shrinks nor stretches, but retains the same length. This is known as the neutral line or neutral axis. Figure 5-44 illustrates the neutral axis of a bend. It is along this neutral axis that bend allowance is computed.

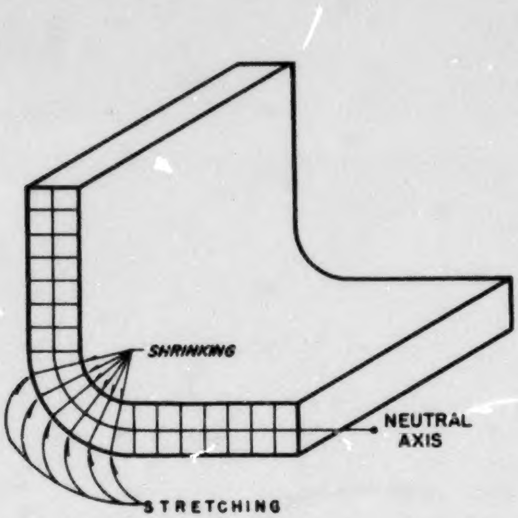
BEND ALLOWANCE TERMS

Familiarity with the following terms is necessary for an understanding of bend allowance and its application to an actual bending job. Figure 5-45 illustrates most of these terms.

Leg. The longer part of a formed angle.

Flange. The shorter part of a formed angle—the opposite of leg. If each side of the angle is the same length, then each is known as a leg.

Mold Line (ML). The line formed by extending the outside surfaces of the leg and flange. (An imaginary point from which real base measurements are provided on drawings.)



AM.286

Figure 5-44.—Neutral axis.

Bend Tangent Line (BL). The line at which the metal starts to bend and the line at which the metal stops curving. All the space between the bend tangent lines is the bend allowance.

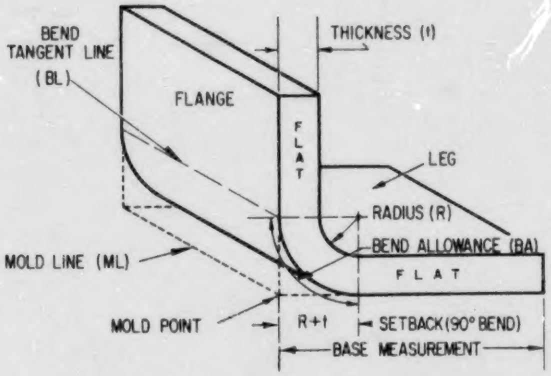
Bend Allowance (BA). The amount of material consumed in making a bend.

Radius (R). The radius of the bend–always to the inside of the metal being formed unless otherwise stated. (The minimum allowable radius for bending a given type and thickness of material should always be ascertained before proceeding with any bend allowance calculations.)

Setback (SB). The setback is the distance from the bend tangent line to the mold point. In a 90-degree bend SB = R + T (radius of the bend plus thickness of the metal). The setback dimension must be determined prior to making the bend as it (setback) is used in determining the location of the beginning bend tangent line.

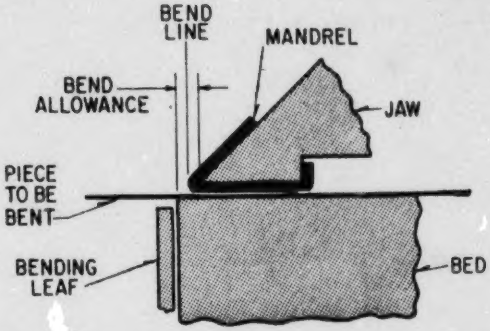
Bend Line (also called BRAKE or SIGHT line). The layout line on the metal being formed which is set even with the nose of the brake and serves as a guide in bending the work. (Before forming a bend, it must be decided which end of the material can be most conveniently inserted in the brake. The bend line is then measured and marked off with a soft-lead pencil from the bend tangent line closest to the end which is to be placed under the brake. This measurement should be equal to the radius of the bend. The metal is then inserted in the brake so that the nose of the brake will fall directly over the bend line, as shown in figure 5-46.)

Flat (short for flat portion). The flat portion or flat of a part is that portion not included in the bend. It is equal to the base measurement minus the setback.



AM.287

Figure 5-45.—Bend allowance terms.



AM.288

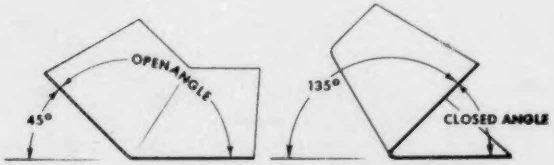
Figure 5-46.—Locating bend line in brake.

Base Measurement. The base measurement is the outside dimensions of a formed part. Base measurement will be given on the drawing or blueprint, or may be obtained from the original part.

Closed Angle. An angle that is less than 90 degrees when measured between legs, or more than 90 degrees when the amount of bend is measured. (See fig. 5-47.)

Open Angle. An angle that is more than 90 degrees when measured between legs, or less than 90 degrees when the amount of bend is measured.

K No. One of 179 numbers on the K chart corresponding to one of the angles between 0 and 180 degrees to which metal can be bent. (See table 5-2). Whenever metal is to be bent to any angle other than 90 degrees (K No. of 1.0), the corresponding K No. is selected from the chart and is multiplied by the sum of the radius and the thickness of the metal. The product is the amount of setback for the bend.



AM.289

Figure 5-47.—Open and closed angles.

BEND ALLOWANCE FORMULA

By experimentation with actual bends in metals, aircraft engineers have found that accurate bending results could be obtained by using the following formula for any degree of bend from 1 to 180.

$$(0.01743 \times R + 0.0078 \times T) \times N = BA$$

where

R equals the desired bend radius,
T equals thickness of the material, and
N equals number of degrees of bend.

Table 5-3 shows the bend allowance per degree of bend for some commonly used thicknesses, and bend radii used in aircraft construction. This table is based on the foregoing formula. The blank spaces on the table are spaces where values were omitted because the bends would be too sharp for satisfactory production.

LAYOUT PRACTICES

In laying out metal prior to bending it to a desired shape, there are certain precautions which should be observed. In the following paragraphs are some of the more important precautions; for information on the use of layout tools refer to Tools and Their Uses, NavPers 10085-B.

Every precaution must be taken to avoid marring aluminum-alloy sheet and even steel sheet should be carefully handled. To protect the under surface of the material from any possible damage, it is often advisable to place a piece of heavy paper, felt, or plywood between the material and the working surface. In working with a large sheet of material, it is important to avoid bending it; hence, it is a good idea to have a helper in placing it on the working surface.

A layout fluid should be applied to the surface of the metal so that the pattern will stand out clearly. Any one of several approved fluids may be used. Zinc chromate and bluing fluid are two of the most commonly used. Since zinc chromate protects a metal surface against corrosion and also serves as a base for paint, it need not be removed after the layout is completed. Bluing fluid is merely a blue dye dissolved in alcohol. It does not protect metal against corrosion or serve as a paint binder, so it should be removed either with ordinary paint thinner or alcohol.

To begin the layout, one edge of the metal should be straight. Use the squaring shears if necessary, then test the job with a straightedge. All measurements can then be based on the straight edge of the sheet. Lines at a known angle or parallel to the straight edge can be made by marking off points from a combination square held firmly against the straight edge.

Table 5-2.–K chart.

A°	K No.	A°	K No.	A°	K No.	A°	K No.
1	0.00873	46	0.42447	91	1.0176	136	2.4751
2	.01745	47	.43481	92	1.0355	137	2.5386
3	.02618	48	.44523	93	1.0538	138	2.6051
4	.03492	49	.45573	94	1.0724	139	2.6746
5	.04366	50	.46631	95	1.0913	140	2.7475
6	.05241	51	.47697	96	1.1106	141	2.8237
7	.06116	52	.48773	97	1.1303	142	2.9042
8	.06993	53	.49858	98	1.1504	143	2.9887
9	.07870	54	.50952	99	1.1708	144	3.0777
10	.08749	55	.52057	100	1.1917	145	3.1716
11	.09629	56	.53171	101	1.2131	146	3.2708
12	.10510	57	.54295	102	1.2349	147	3.3759
13	.11393	58	.55431	103	1.2572	148	3.4874
14	.12278	59	.56577	104	1.2799	149	3.6059
15	.13165	60	.57735	105	1.3023	150	3.7320
16	.14054	61	.58904	106	1.3270	151	3.8667
17	.14945	62	.60086	107	1.3514	152	4.0108
18	.15838	63	.61280	108	1.3764	153	4.1653
19	.16734	64	.62487	109	1.4019	154	4.3315
20	.17633	65	.63707	110	1.4281	155	4.5107
21	.18534	66	.64941	111	1.4550	156	4.7046
22	.19438	67	.66188	112	1.4826	157	4.9151
23	.20345	68	.67451	113	1.5108	158	5.1445
24	.21256	69	.68728	114	1.5399	159	5.3995
25	.22169	70	.70021	115	1.5697	160	5.6713
26	.23087	71	.71329	116	1.6003	161	5.9758
27	.24008	72	.72654	117	1.6318	162	6.3137
28	.24933	73	.73396	118	1.6643	163	6.6911
29	.25862	74	.75355	119	1.6977	164	7.1154
30	.26795	75	.76733	120	1.7320	165	7.5957
31	.27732	76	.78128	121	1.7675	166	8.1443
32	.28674	77	.79543	122	1.8040	167	8.7769
33	.29621	78	.80978	123	1.8418	168	9.5144
34	.30573	79	.82434	124	1.8807	169	10.385
35	.31530	80	.83910	125	1.9210	170	11.430
36	.32492	81	.85408	126	1.9626	171	12.706
37	.33459	82	.86929	127	2.0057	172	14.301
38	.34433	83	.88472	128	2.0503	173	16.350
39	.35412	84	.90040	129	2.0965	174	19.081
40	.36397	85	.91633	130	2.1445	175	22.904
41	.37388	86	.93251	131	2.1943	176	26.636
42	.38386	87	.94896	132	2.2460	177	38.188
43	.39391	88	.96569	133	2.2998	178	57.290
44	.40403	89	.98270	134	2.3558	179	114.590
45	.41421	90	1.00000	135	2.4142	180	Infinite

Table 5-3.—Bend allowance per degree of bend.

	THICKNESS					
RADIUS	0.020	0.025	0.032	0.040	0.050	0.063
1/32	0.00070	0.00074	0.00079			
1/16	.00125	.00129	.00135	0.00140	0.00148	0.00158
3/32	.00179	.00183	.00188	.00195	.00202	.00212
1/8	.00234	.00238	.00243	.00249	.00257	.00267
5/32	.00288	.00292	.00297	.00304	.00311	.00321
3/16	.00342	.00347	.00352	.00358	.00366	.00376
7/32	.00397	.00401	.00406	.00412	.00420	.00430
1/4	.00451	.00455	.00461	.00467	.00475	.00485

If it is impossible to obtain a straight edge on a sheet to start a layout, or if the distance from the edge is too great, a reference line may be used. The reference line may be made by connecting any two points with a straight line. Perpendiculars may be erected to the reference line by using a compass or dividers, thus forming a cross. Once the cross is accurately laid out, it may be used as a basis for almost any type of fitting layout.

A scriber must never be used for drawing lines on aluminum or magnesium except to indicate where the metal is to be cut or drilled. All other lines must be drawn with a soft-lead pencil. Folding a piece of metal along a sharp line made with a scriber will weaken the metal and possibly cause it to crack along the bend. If it does not crack at the time of bending, it is very susceptible to cracking in service, possibly at a time when failure of the part can be catastrophic.

CHAPTER 6

AIRCRAFT HARDWARE

Aircraft hardware is a term used in reference to a great many items used in aircraft construction. Some hardware, such as electrical and powerplant hardware, is not applicable to the AMS rating. The AMS is concerned with such hardware as rivets, turnlock fasteners, bolts, screws, nuts, washers, wire and cables, and related hardware.

Because of the small size of most hardware items, their importance is often overlooked; however, the safe and efficient operation of any aircraft is greatly dependent upon correct selection and use of aircraft structural hardware. This chapter discusses these various items, and provides information which will aid in the selection and correct use of aircraft structural hardware.

RIVETS

Every AMS should be a skilled riveter. The fact that there are hundreds of thousands of rivets in the airframe of some of our late model tactical aircraft is an indication of how important riveting is in the work of the AMS. A glance at any aircraft will disclose the thousands of rivets in the outer skin alone. In addition to the riveted skin, rivets are also used for joining spar sections, for holding rib sections in place, for securing fittings to various parts of the aircraft, and for fastening innumerable bracing members and other parts together. Rivets that are satisfactory for one part of the aircraft are often unsatisfactory for another part. It is therefore important that the AMS know the strength and driving properties of the various types of rivets and how to identify them as well as how to drive or otherwise install them.

SOLID RIVETS

Solid rivets are classified by their head shape, by the material from which they are manufactured, and by their size. Rivet head shapes and their identifying code numbers are shown in figure 6-1. The prefix MS identifies hardware under the cognizance of the Department of Defense and the item conforms to written military standards. The prefix AN identifies specifications which are developed and issued under joint authority of the Air Force-Navy.

Countersunk-head rivets. Countersunk-head rivets, often referred to as FLUSH RIVETS, are used where streamlining is important. On combat aircraft, practically all external surfaces are flush riveted. Countersunk-head rivets are obtainable with heads having an included angle of 78 and 100 degrees. The 100-degree is the most commonly used type.

Universal-head rivets. Universal-head rivets offer only slight resistance to airflow and are, therefore, frequently used on external surfaces, especially on helicopters, transports, and other low-speed aircraft where aerodynamic smoothness is not of prime importance.

Rivet Identification Code

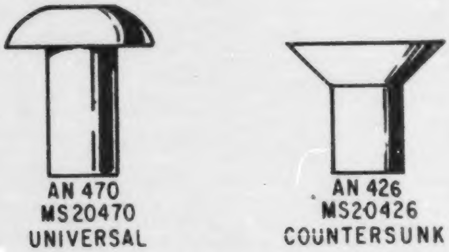
The rivet codes as shown in figure 6-1 are sufficient to identify rivets only as to head shape. To be meaningful and precisely identify a rivet, certain other information is encoded and added to the basic code.

A letter or letters following the head-shape code identify the material or alloy from which the rivet was made. (Table 6-1 includes a listing of the most common of these codes.) The alloy code is followed by two numbers separated by a dash. The first number is the numerator of a fraction which specifies the shank diameter in thirty-seconds of an inch. The second number is the numerator of a fraction in sixteenths of an inch and identifies the length of the rivet. The rivet code is illustrated in figure 6-2.

Rivet Composition

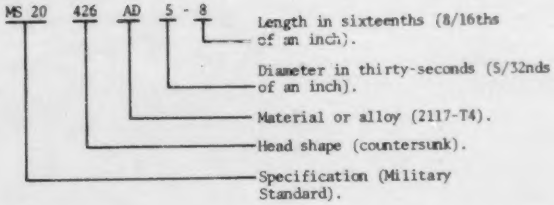
Most of the rivets used in aircraft construction are made of aluminum alloy. A few types, used for special purposes, are made of mild steel, Monel, titanium, and copper. Of the aluminum alloy rivets, those made of 1100, 2117, 2017, 2024, and 5056 are considered standard. (See table 3-4 in ch. 3 for composition of various alloys.)

Alloy 1100 rivets. Alloy 1100 rivets are supplied in the "as fabricated" (F) temper and are driven in this condition. No further treatment is required and the rivet properties do not change with prolonged periods of storage. They are relatively soft and easy to drive. The cold work resulting from driving increases their strength slightly. The 1100-F rivets are used only for riveting nonstructural parts. These rivets are identified by their plain head. (See table 6-1.)



AM.311

Figure 6-1.—Rivet head shapes and code numbers.


MS 20
426
AD
5 - 8
Length in sixteenths (8/16ths of an inch).
Diameter in thirty-seconds (5/32nds of an inch).
Material or alloy (2117-T4).
Head shape (countersunk).
Specification (Military Standard).

AM.312

Figure 6-2.—Rivet coding example.

Alloy 2117 rivets. Like the 1100-F rivets, these rivets need no further treatment when received from the manufacturer, and can be stored indefinitely. They are furnished in the solution-heat-treated (T4) temper, but will change to the solution-heat-treated-and-cold-worked (T3) temper after driving. The 2117-T4 rivet is in general use throughout aircraft structures and is by far the most widely used rivet, especially in repair work. In most cases the 2117-T4 rivet may be substituted for 2017-T4 and 2024-T4 rivets for repair work by using the next larger diameter of rivet. This is desirable since both the 2017-T4 and 2024-T4 rivets must be heat treated prior to using, or kept in cold storage. The 2117-T4 rivets are identified by a dimple in the head.

Alloy 2017 and 2024 rivets. As mentioned in the preceding paragraph, both these rivets are supplied in the T4 temper and must be heat treated. These rivets must be driven within 20 minutes after quenching or refrigerated at 32° F or lower which will delay the aging time 24 hours. If either time is exceeded, reheat treatment is required. These rivets may be reheated as many times as desirable provided the proper solution heat-treatment temperature is not exceeded. The 2024-T4 rivets are stronger than the 2017-T4 and are therefore harder to drive. The 2017-T4 rivet is identified by the raised teat on the head, while the 2024-T4 has two raised dashes on the head.

Alloy 5056 rivets. These rivets are used primarily for joining magnesium alloy structures because of their corrosion resistant qualities when used with magnesium. They are supplied in the H32 temper (strain-hardened and then stabilized). These rivets are identified by a raised cross on the head. 5056-H32 rivets may be stored indefinitely with no change in driving characteristics.

HI-SHEAR RIVETS

Hi-shear (pin) rivets are essentially threadless bolts. The pin is headed at one end and is

Table 6-1.–Rivet material identification.

Material or alloy	Code letters	Head marking on rivet
1100-F	A	Plain ○
2117-T4	AD	Indented dimple ◎
2017-T4	D	Raised teat ◎
2024-T4	DD	Raised double dash ⊖
5056-H32	B	Raised cross ⊕

grooved about the circumference at the other. A metal collar is swaged onto the grooved end, effecting a firm tight fit. They are available in two head styles, the flat protruding head and the flush 100-degree countersunk head. Hi-Shear rivets are made in a variety of materials and are used only in shear applications. Due to the shear strength being greater than either the shear or bearing strength of aluminum alloys, they are used to greater advantage only in the thicker gage sheets. They are never used where the grip length is less than the shank diameter. Hi-Shear rivets are illustrated in figure 6-3.

Rivet Identification

Hi-Shear rivets are identified by code numbers similar to the solid rivets. The size of the rivet is measured in increments of thirty-seconds of an inch for the diameter and sixteenths of an inch for the rivet grip length. Thus an NAS1055-5-7 rivet would be a Hi-Shear rivet with a countersunk head, its diameter would be 5/32-inch, and its maximum grip length would be 7/16-inch.

The collars are identified by a basic code number and a dash number which corresponds to the dash number for the diameter of the rivet. An A before the dash number indicates an aluminum alloy collar. An NAS528-A5 collar would be used on a 5/32-inch diameter rivet pin. Repair procedures involving the installation or replacement of Hi-Shear rivets generally specify the collar to be used.

BLIND RIVETS

There are many places on an aircraft where access to both sides of a riveted structural part is

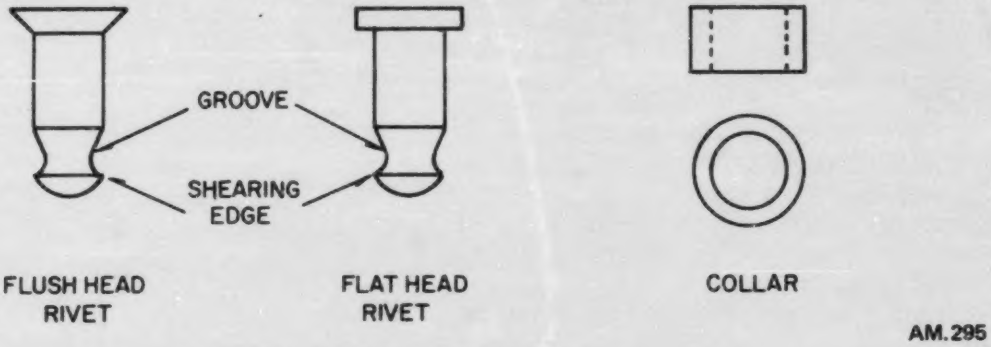


Figure 6-3.–Hi-Shear rivet installation.

impossible, or where limited space does not permit the use of a bucking bar. Furthermore, in the attachment of many non-structural parts, such as aircraft interior furnishings, flooring, deicing boots, flotation equipment, and the like, the full strength of solid shank rivets is not necessary and their application would add extra weight to the aircraft thereby reducing the payload.

For use in such places, rivets have been designed which can be formed from the outside. They are lighter than solid shank rivets, yet amply strong. These rivets are manufactured by various corporations and have characteristic peculiarities, chief of which is the requirement of special installation tools. Rivets in this category are commonly referred to as blind rivets because of the self-heading feature.

Self-Plugging Rivet. The self-plugging rivet (friction lock) retains the stem in position by friction. The stem is drawn up into the rivet shank and the mandrel portion of the stem upsets the shank on the blind side, forming a plug in the hollow center of the rivet. The excess portion of the stem breaks off at a groove due to the continued pulling action of the rivet gun or tool. The two styles or rivet heads are the universal and the 100-degree countersunk. These correspond to the MS20470 and MS20426 solid rivets, respectively. Materials used are 2117-T4 and 5056-F aluminum alloys, and Monel for special application. The shank diameter and grip lengths are designated by dash numbers after the basic number. The first dash number indicates the shank diameter in thirty-seconds of an inch and the second number indicates the grip length in sixteenths of an inch. The material code is the same as for solid rivets.

Pull-Through Rivets. Pull-through rivets are essentially the same as the self-plugging rivets, except that when the mandrel pulls on the stem, the stem forms the head on the rivet shank, then pulls all the way through the shank, leaving a hole in the rivet.

The same installation tools are used for the self-plugging (friction lock) and pull-through rivets. Table 6-2 shows the basic rivet types with basic numbers. Figure 6-4 illustrates the installation of both types of rivets.

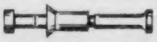
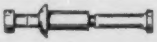
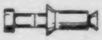
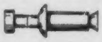
Self-Plugging rivets (mechanical lock). Figure 6-5 illustrates a blind rivet that operates on the same principle as the friction lock rivets, both employing a mandrel stem and a hollow shank. The main difference between the friction lock and mechanical lock rivets is in the method of pin retention; the friction lock relies on friction alone for pin retention, while the mechanical lock rivet employs a mechanical lock between the head of the rivet and the pull stem. Note in view B that the collar, shown clearly in view A attached to the head, has been driven into the head and has assumed a wedge or cone shape around the groove in the pin. This holds the shank firmly in place from the head side.

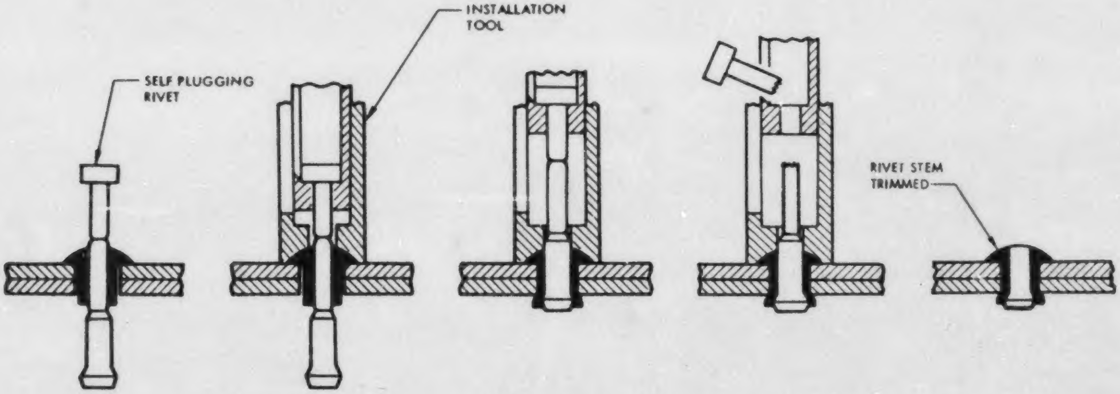
The self-plugging rivet is made of 5056-H14 aluminum alloy and includes the conical recess and locking collar in the rivet head. The stem is made of 2024-T36 aluminum alloy. Pull grooves which fit into the jaws of the rivet gun are provided on the stem end that protrudes above the rivet head. The blind end portion of the stem incorporates a head and a land with an extruding angle which expands the rivet shank.

Applied loads permissible for self-plugging rivets are comparable to those for solid shank rivets of the same shear strength, regardless of sheet thickness. The composite ultimate shear strength of the 5056-H14 shank and the 2024-T36 pin exceeds 38,000 psi on standard rivet hole diameter; their tensile strength is in excess of 28,000 psi. Pin retention characteristics are excellent in these rivets and the possibility of the pin working out is minimized by the lock formed in the rivet head.

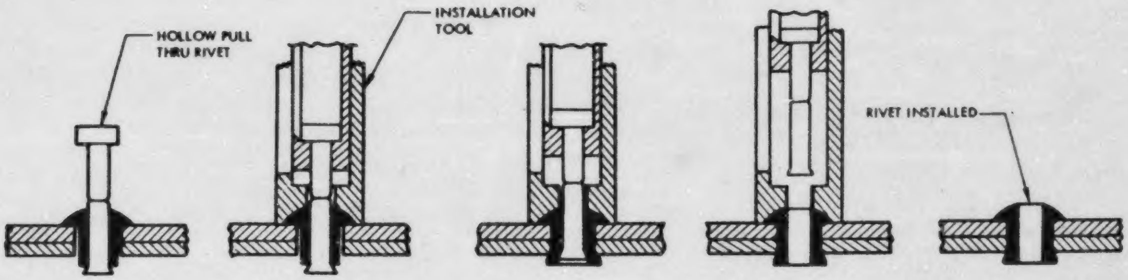
Rivnuts. The Rivnut is a hollow rivet made of 6063 aluminum alloy, counterbored and threaded on the inside. Installation is ac-

Table 6-2.—Rivet types with basic numbers.

TYPE	CONFIGURATION	HEAD IDENTIFICATION	BASIC NUMBER
SELF PLUGGING		100 DEGREE COUNTERSINK	MS20601
		UNIVERSAL HEAD	MS20600
HOLLOW PULL THRU		100 DEGREE COUNTERSINK	MS20605
		UNIVERSAL HEAD	MS20604



SELF PLUGGING



PULL THRU

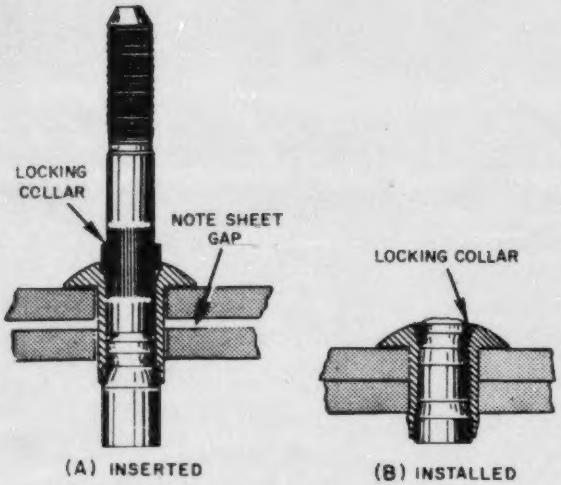
AM.315

Figure 6-4.–Self-plugging (friction lock) and pull-through rivet installation.

complished with the aid of a special tool, which heads the rivet on the blind side of the work. Rivnuts are primarily used as a nut plate, as in the attachment of deicer boots; however, they may be used as rivets in secondary structures, or for the attachment of accessories such as instruments, brackets, and soundproofing materials. After a suitable group of Rivnuts has been installed, accessories can be fastened in place with screws.

Rivnuts are manufactured in two head styles, flat and countersunk, and in two shank designs, open and closed ends, as shown in figure 6-6. Each of these rivets is available in three sizes–Nos. 6-32, 8-32, and 10-32. These numbers indicate the nominal diameter and the actual number of threads per inch of the machine screw that fits into the Rivnut. Rivnuts are available with our without small projections, called keys, attached to the underside of the head to keep the Rivnut from turning. Keyed Rivnuts are used when the Rivnut serves as a nut plate, while Rivnuts without keys are used for straight blind riveting jobs where no torque loads are imposed.

Open-end Rivnuts are the most widely used and are recommended in preference to the closed-end type, except in sealed flotation or pressurized compartments, in which cases the closed-end Rivnut must be used.

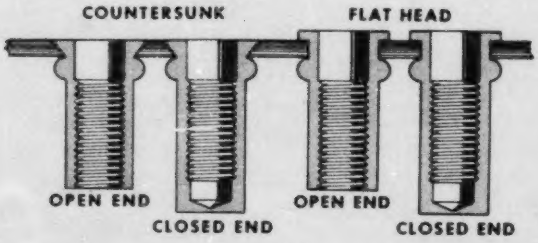


AM.316
Figure 6-5.—Self-plugging rivet (mechanical lock).

LOCKBOLT FASTENERS

Lockbolt fasteners are designed to meet high-strength requirements. Used in many structural applications, their shear and tensile strengths equal or exceed the requirements of AN and NAS bolts.

Lockbolt Pins (tension pull type). The lockbolt shown in figure 6-7 (A) consists of a pin and collar. They are available in two head styles, protruding and countersunk. Pin retention is accomplished by swaging the collar into the locking grooves on the pin.

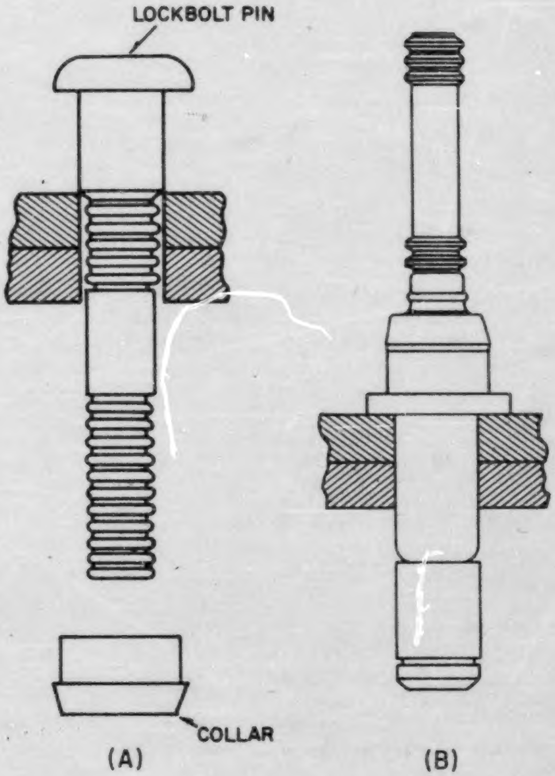


AM.317
Figure 6-6.—Sectional view of Rivnut showing head and end designs.

Blind Lockbolt. The blind lockbolt shown in figure 6-7 (B) is similar to the self-plugging rivet shown in figure 6-5. It features a positive mechanical lock for pin retention.

TURNLOCK FASTENERS

Turnlock fasteners are used to secure inspection plates, doors, and other removable panels on aircraft. Turnlock fasteners are also referred to by such terms as quick-opening, quick-action, and stressed-panel fasteners. The most desirable feature of these fasteners is that they permit quick and easy removal of access panels for inspection and servicing purposes. Removal and



AM.297
Figure 6-7.—Lockbolts.

replacement of damaged turnlock fasteners is one of the responsibilities of the AMS.

Turnlock fasteners are manufactured and supplied by a number of manufacturers under various trade names. Some of the most commonly used are the Dzus (pronounced zoo'-s), Camloc, and Airloc, all of which are discussed in the following sections.

CAMLOC FASTENERS

The 4002 series Camloc fasteners consist of four principal parts–the receptacle, the grommet, the retaining ring, and the stud assembly. (See fig. 6-8.) The receptacle consists of an aluminum alloy forging mounted in a stamped sheet-metal base. The receptacle assembly is riveted to the access door frame, which is attached to the structure of the aircraft. The grommet is a sheet-metal ring held in the access panel with the retaining ring. Grommets are furnished in two types, the flush type and the protruding type. In addition to serving as a grommet for the hole in the access panel, it also holds the stud assembly. The stud assembly consists of a stud, a cross pin, spring, and a spring cup. The assembly is so designed that it can be quickly inserted into the grommet by

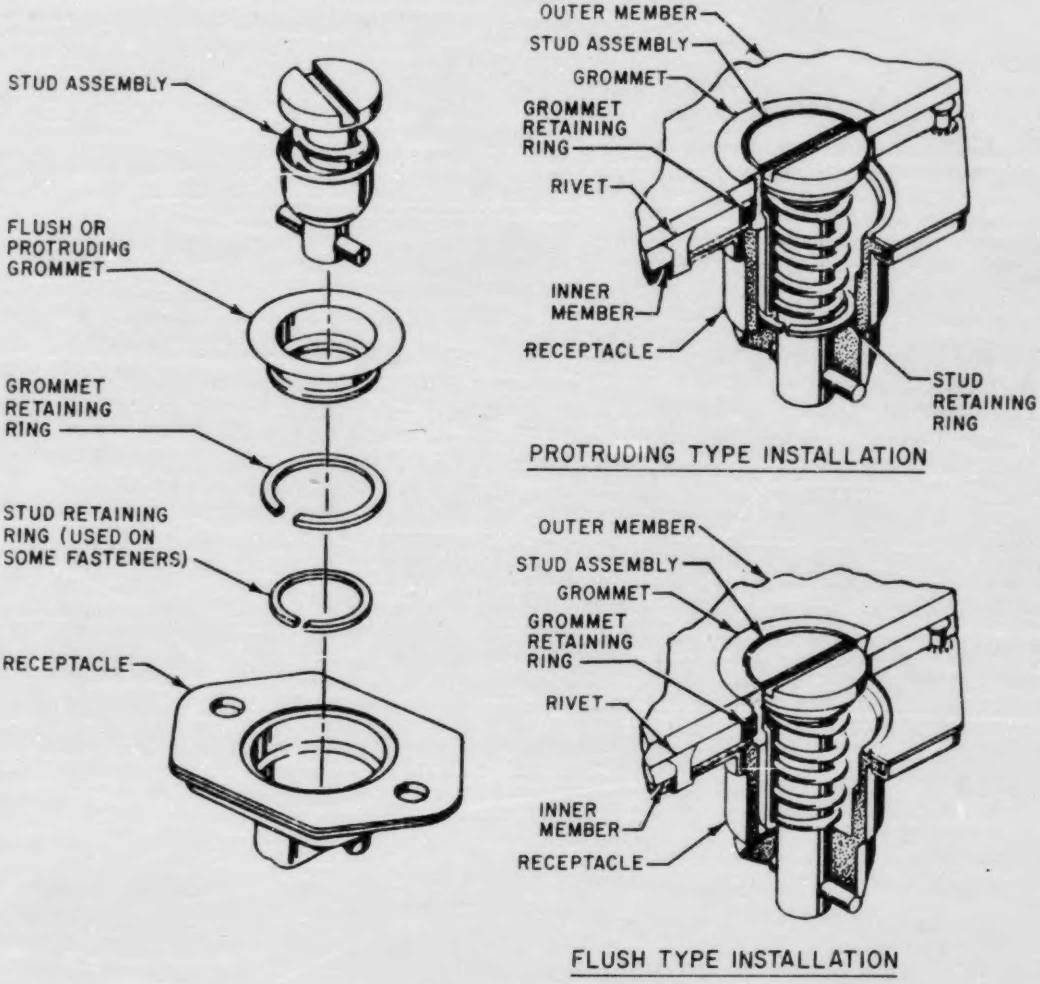


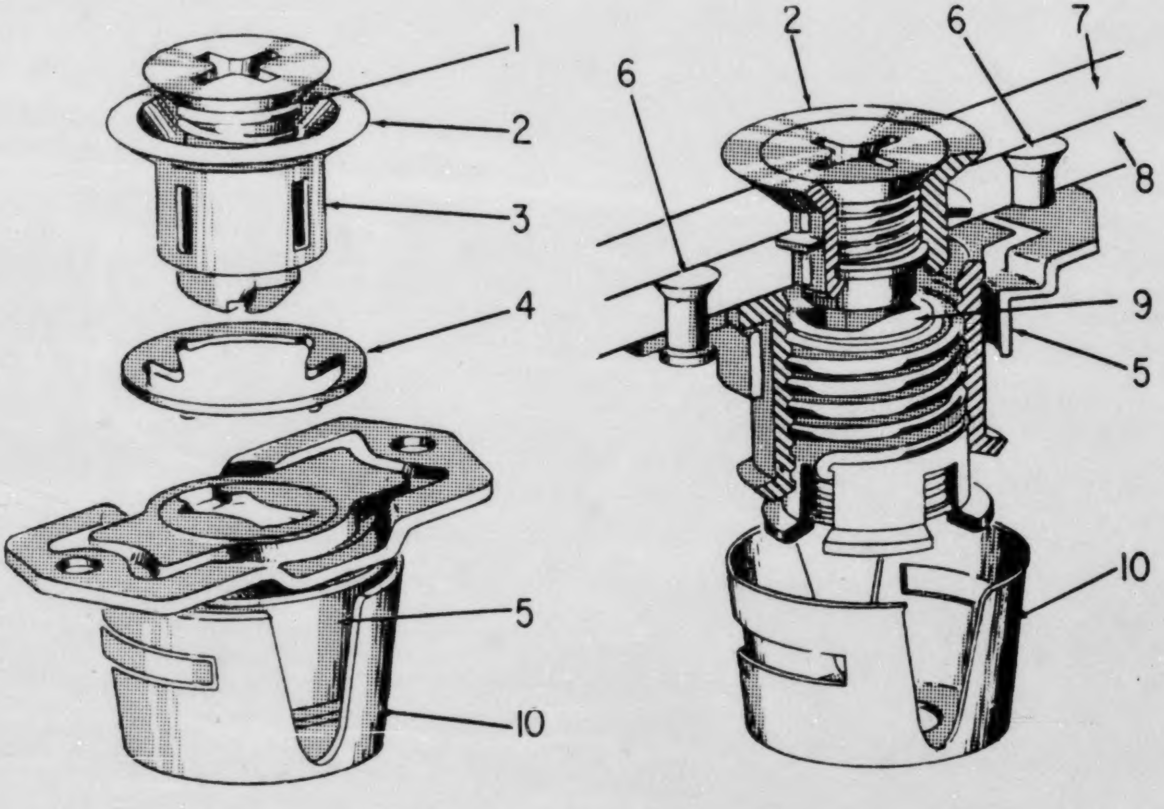
Figure 6-8.–Camloc 4002 series fastener.

compressing the spring. Once installed in the grommet, the stud assembly cannot be removed unless the spring is again compressed.

CAMLOC HIGH-STRESS PANEL FASTENERS

The Camloc high-stress panel fastener shown in figure 6-9 is a high-strength, quick release, rotary type fastener and may be used on flat or curved, inside or outside panels. The fastener may have either a flush or protruding stud. The studs are held in the panel with flat or cone-shaped washers, the latter being used with flush fasteners in dimpled holes. This fastener may be distinguished from screws by the deep No. 2 Phillips recess in the stud head and by the bushing in which the stud is installed.

A threaded insert in the receptacle provides an adjustable locking device. As the stud is inserted and turned counterclockwise 1/2 turn or more, it screws out the insert sufficiently to permit the stud key to engage the insert cam when turned clockwise. Rotating the stud



AM.39

1. Tension spring.
2. Stud assembly.
3. Bushing.
4. Retaining ring.
5. Receptacle assembly.
6. Receptacle attaching rivets.
7. Outer skin.
8. Inner skin.
9. Insert.
10. Cover.

Figure 6-9.—Camloc high-stress panel fastener.

clockwise 1/4 turn engages the insert, and continued rotation screws the insert in, tightening the fastener. Turning the stud 1/4 turn counterclockwise will release the stud, but will not screw the insert out far enough to permit reengagement on installation. The stud should be turned at least 1/2 turn counterclockwise to reset the insert.

AIRLOC FASTENERS

Figure 6-10 illustrates the parts that make up an Airloc fastener. As with the Camloc fastener, the Airloc fastener also consists of a receptacle, a stud, and a cross pin. The stud is attached to the access panel and is held in place by the cross pin. The receptacle is riveted to the access panel frame.

Two types of Airloc receptacles are available—the fixed type (insert A) and the floating type (insert B). The floating type makes for easier alignment of the stud in the receptacle. Several types of studs are also available, but in each instance the stud and cross pin come as separate units so that the stud may be easily installed in the access panel.

The Airloc receptacle is fastened to the inner surface of the access panel frame by two rivets. Rivet heads must be flush with the outer surface of the panel frame. When replacing receptacles, drill out the two old rivets and attach the new receptacle by flush riveting. Be careful not to

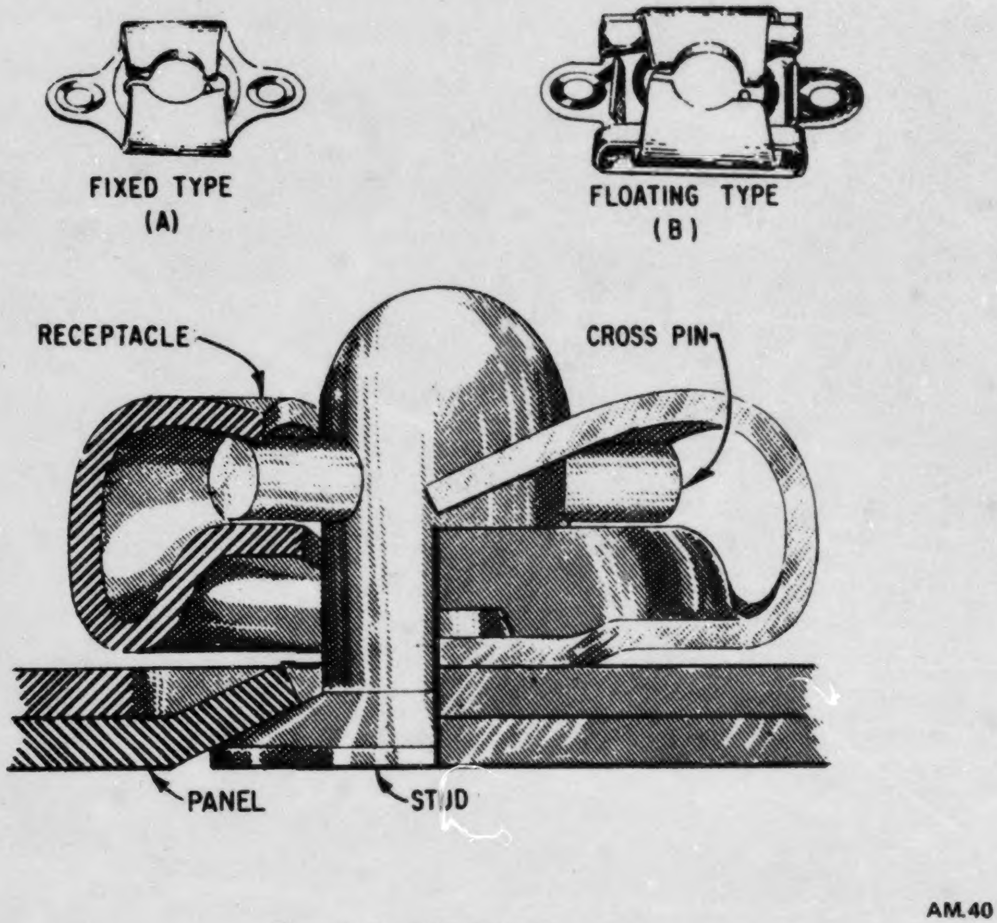


Figure 6-10.—Airloc fastener.

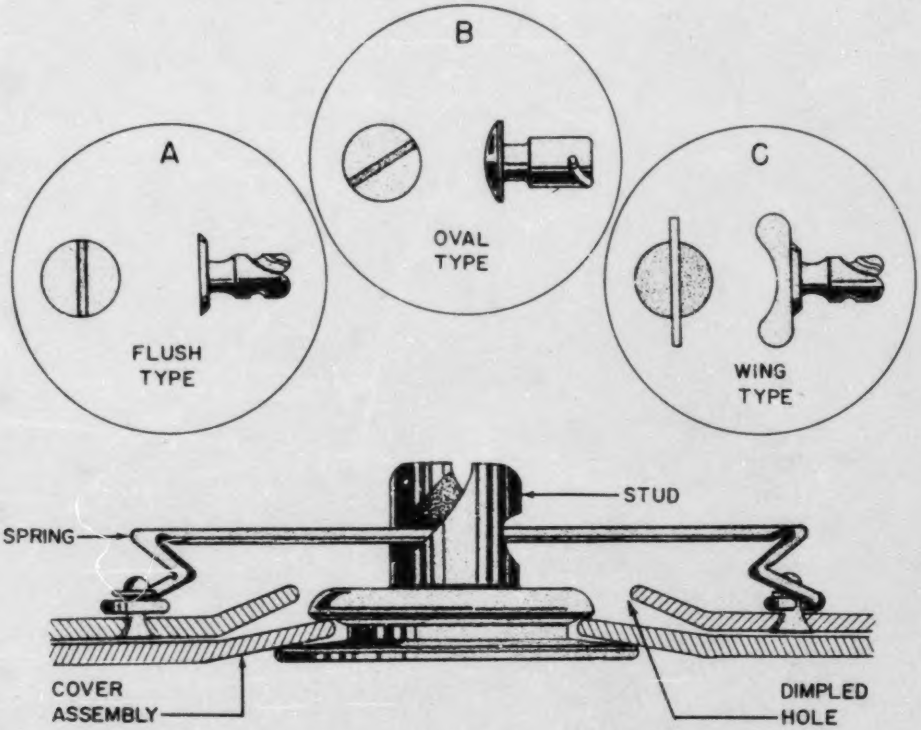
mar the sheet. When inserting the stud and cross pin, insert the stud through the access panel and, by use of a special handtool, insert the cross pin in the stud. Cross pins can be removed by means of special ejector pliers.

DZUS FASTENERS

Dzus fasteners are available in two types. One is the light-duty type, used on box covers, access hole covers, and lighweight fairing. The second is the heavy-duty type, which is used on cowling and heavy fairing. The main difference between the two types of Dzus fasteners is a grommet, used by heavy-duty but not by light-duty fasteners. Otherwise their construction features are about the same.

Figure 6-11 shows the parts making up a light-duty Dzus fastener. Notice that they include a spring and a stud. The spring is made of cadmium-plated steel music wire and is usually riveted to an aircraft structural member. The stud comes in a number of designs (as shown in insets A, B, and C) and mounts in a dimpled hole in the cover assembly.

When the panel or plate is being positioned on the aircraft preparatory to securing it in place, the spring riveted to the structural member enters the hollow center of the stud, which is retained in the plate or panel. Then, when the stud is turned about 1/4 turn, the curved jaws of the stud slip over the spring and compress it. The resulting tension locks the stud in place thereby securing the panel or plate.



AM.319

Figure 6-11.—Dzus fastener.

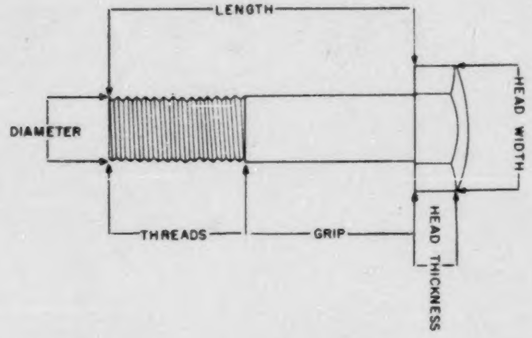
THREADED FASTENERS

BOLTS

Many types of bolts are used on aircraft and each type is used to fasten something in place. However, before discussing some of these types, it might be helpful at this point to list and explain some commonly used bolt terms. The AMS should know the names of bolt parts. He should also be aware of the bolt dimensions that must be considered in selecting a bolt. Figure 6-12 illustrates both types of information.

The three principal parts of a bolt are the HEAD, THREAD, and GRIP. It is possible that two of these parts are well known but perhaps the "grip" is an unfamiliar term. If so, notice that the grip is the unthreaded part of the bolt shaft and that it extends from the threads to the bolthead. The head is the larger diameter of the bolt and may be one of many shapes or designs. The head retains the bolt in place in one direction and the nut used on the threads retains it in the other direction.

In order to choose the correct replacement for an unserviceable bolt, several bolt dimensions must be considered, one being the length of the bolt. As shown in figure 6-12, the bolt length is the distance from the tip of the threaded end to the head of the bolt. Correct length selection is indicated when the chosen bolt extends through the nut at least 1/32 inch in the case of flat-end bolts (fig.6-12) or in the case of chamfered (rounded) end bolts, at least one full chamfer should extend through the nut. If the bolt is too short, it may not extend out of the bolthole far enough for the nut to be securely fastened. If it is too long, it may extend so far that it interferes with the movement of nearby aircraft parts. Unnecessarily long bolts, especially in numbers, can affect weight and balance and reduce the aircraft payload capacity.



AM.320

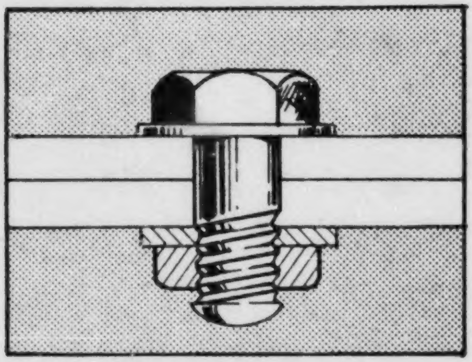
Figure 6-12.—Bolt terms and dimensions.

In addition, if a bolt is too long or too short, its grip will usually be the wrong length. As shown in figure 6-13, grip length should be approximately the same as the thickness of the material to be fastened. If the grip is too short, the threads of the bolt will extend into the bolthole and may act like a reamer when the material is vibrating. To prevent this, make certain that no more than two threads extend into the bolthole. Also make certain that any threads that enter the bolthole extend only into the thicker member that is being fastened. If the grip is too long, the nut will run out of threads before it can be tightened. In this event a bolt with a shorter grip should be used, or if the bolt grip extends only a short distance through the hole, a washer may be used.

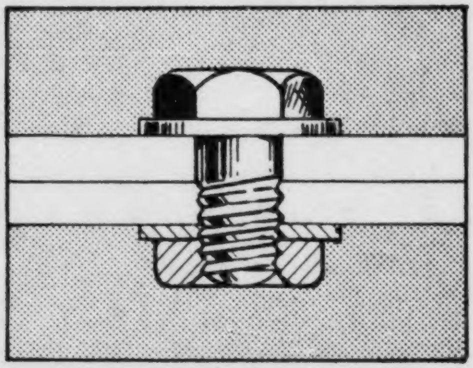
A second bolt dimension that must be considered is diameter. As shown in figure 6-12, the diameter of the bolt is the thickness of its shaft. If this thickness is 1/4 inch or more, the bolt diameter is usually given in such fractions of an inch as 1/4, 5/16, 7/16, 1/2, and the like. However, if the bolt is less than 1/4 inch thick, the diameter is usually expressed as a whole number. For instance, a bolt that is 0.190 inch in diameter is called a No. 10 bolt, while a bolt that is 0.164 inch in diameter is called a No. 8.

The results of using a wrong-diameter bolt should be obvious. If the bolt is too big, it cannot of course enter the bolthole. If the diameter is too small, the bolt has too much play in the bolthole, and the chances are that it is not as strong as the correct size of bolt.

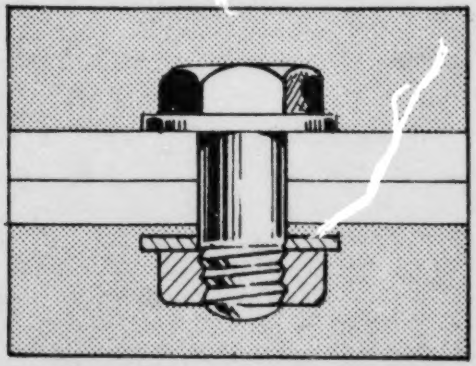
The third and fourth bolt dimensions that should be considered when choosing a bolt replacement are head thickness and width. If the head is too thin or too narrow, it may not be strong enough to bear the load imposed on it. If the head is too thick or too wide, it may extend so far that it interfers with the movement of adjacent aircraft parts.



BOLT GRIP LENGTH CORRECT



BOLT GRIP LENGTH TOO SHORT



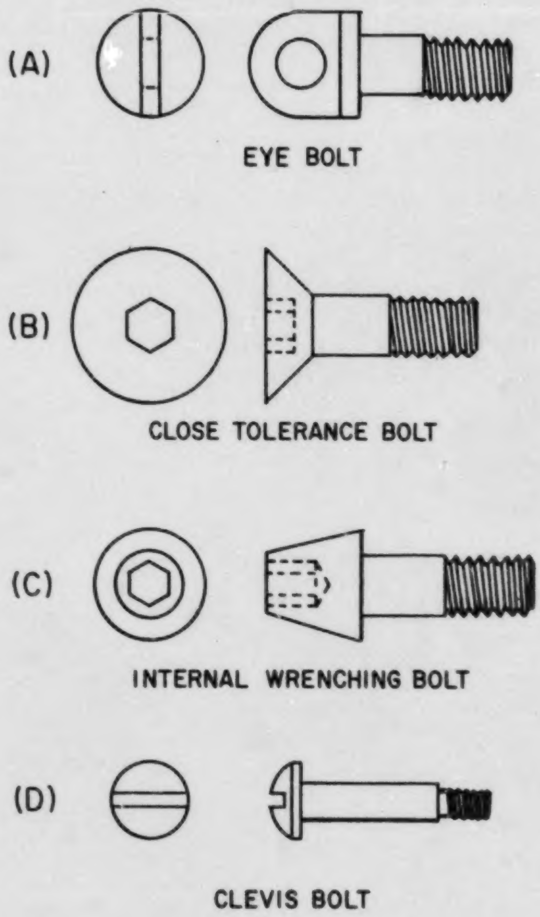
BOLT GRIP LENGTH TOO LONG

AM.321

Figure 6-13.—Correct and incorrect grip lengths.

Boltheads

The most common type of head is the hex head, shown in figure 6-12. This type of head may be thick for greater strength or relatively thin in order to fit in places having limited clearances. In addition, the head may be common or drilled. A hex head bolt may have a single hole drilled through it between two of the sides of the hexagon and still be classed as a common. The drilled head hex bolt has three holes drilled in the head, connecting opposite sides of the hex.



AM.322

Figure 6-14.—Boltheads.

Four additional types of boltheads are shown in figure 6-14. Notice that panel A in that illustration shows an eyebolt, often used in flight control systems. Panel B shows a countersunk head, close tolerance bolt. Panel C shows an internal wrenching bolt. Both the countersunk head bolt and the internal wrenching bolts have hexagonal recesses (six-sided holes) in their heads. They are tightened and loosened by use of appropriate sized Allen wrenches. Panel D shows a clevis bolt with its characteristic round head. This head may be slotted, as shown, to receive a common screwdriver or recessed to receive a Reed and Prince or a Phillips screwdriver.

Bolt Threads

Another structural feature in which bolts may differ is threads. These usually come in one of the two types–coarse or fine, and the two are not interchangeable. For any given size of bolt there are a different number of coarse and fine threads per inch. For instance, consider the 1/4-inch bolts. Some are called 1/4-28 bolts, because they have 28 fine threads per inch. Others have only 20 coarse threads per inch and are called 1/4-20 bolts. To force one size of threads into another size even though both are 1/4 inch will strip the finer threads or softer metal. The same thing is true concerning the other sizes of bolts; therefore, make certain that bolts selected have the correct type of threads.

Bolt Material

The type of metal used in an aircraft bolt helps to determine its strength and its resistance to corrosion. Therefore, make certain that material is considered in the selection of replacement bolts. Like solid shank rivets, bolts have distinctive head markings that help to identify the material from which they are manufactured. In certain cases, aircraft manufacturers are compelled to make bolts of different dimensions or greater strength than the standard types. Such bolts are made for a particular application and it is of extreme importance that like bolts are used in replacement. Such special bolts are usually identified by the letter S stamped on the head. Figure 6-15 shows the tops of several hex-bolt heads, each marked to indicate the type of bolt material.

Bolt Identification

Unless current directives specify otherwise, every unserviceable bolt should be replaced with a bolt of the same type. Of course, substitute and interchangeable items are sometimes available, but the ideal fix is a bolt-for-bolt replacement. The part number of a needed bolt may be obtained by referring to the Illustrated Parts Breakdown (IPB) for the aircraft concerned. Exactly what this part number means depends upon whether the bolt is AN (Air Force-Navy), NAS (National Aircraft Standard) or MS (Military Standard).

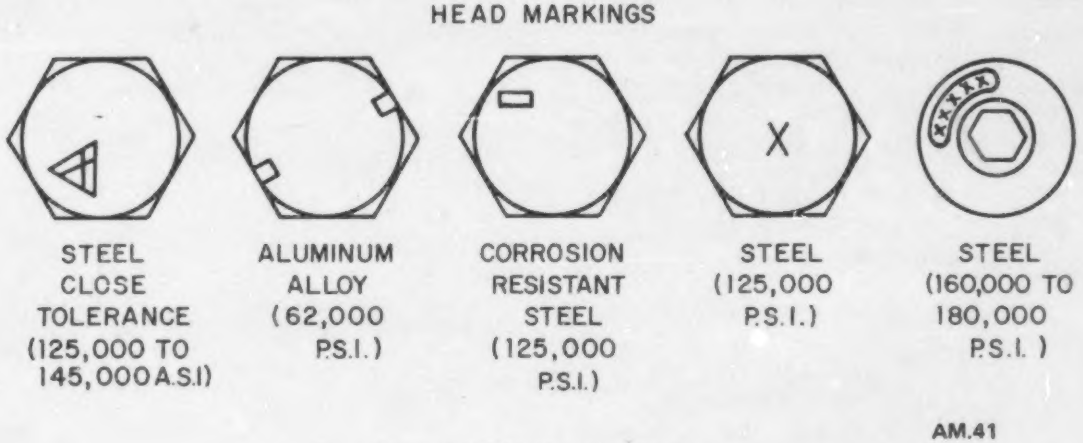
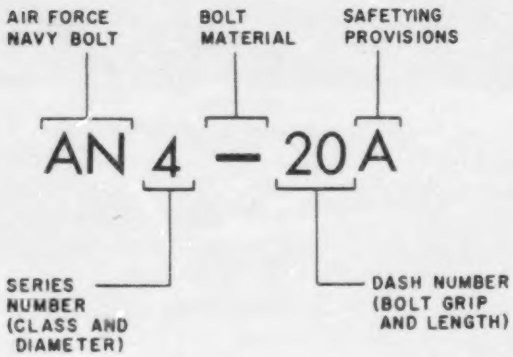

HEAD MARKINGS
X
XXXXX
STEEL CLOSE TOLERANCE (125,000 TO 145,000A.S.I)
ALUMINUM ALLOY (62,000 P.S.I.)
CORROSION RESISTANT STEEL (125,000 P.S.I.)
STEEL (125,000 P.S.I.)
STEEL (160,000 TO 180,000 P.S.I.)
AM.41

Figure 6-15.—Bolthead markings.


AIR FORCE NAVY BOLT
BOLT MATERIAL
SAFETYING PROVISIONS
AN 4 — 20A
SERIES NUMBER (CLASS AND DIAMETER)
DASH NUMBER (BOLT GRIP AND LENGTH)

AM.323

Figure 6-16.—AN bolt part number breakdown.

AN PART NUMBER.—There are several classes of AN bolts, and in some instances their part numbers reveal slightly different types of information. However, most AN numbers contain the same type of information.

Figure 6-16 shows a breakdown of a typical AN bolt part number. Like the AN rivets discussed earlier, it starts with the letters AN. Next, notice that a series number follows the letters AN. This number usually consists of two digits, and the first digit (or absence of it) shows the class of the bolt. For instance, in figure 6-16 the series number has only one digit, and the absence of one digit shows that this part number represents a general-purpose hex-head bolt. However, the part numbers for some bolts of this class have two digits. In fact, general-purpose hex-head bolts include all part numbers beginning with AN3, AN4, and so on through AN20. Other series numbers and the classes of bolts that they represent are as follows:

AN21 through AN36—clevis bolts.
AN42 through AN49—eyebolts.

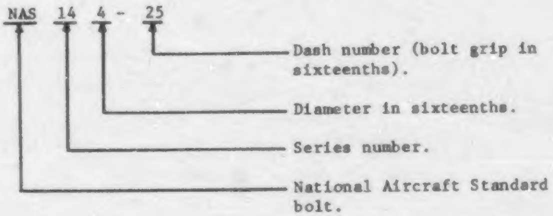
The series number shows another type of information besides bolt 'class. With a few exceptions, it indicates bolt diameter in sixteenths of an inch. For instance, in figure 6-16 the last digit of the series number is 4, so this bolt is 4/16 inch (1/4 inch) in diameter. In the case of a series number ending in 0, for instance AN30, the 0 stands for 10, and the bolt has a diameter of 10/16 inch (5/8 inch).

Refer again to figure 6-16 and notice that a dash follows the series number. When used in the part numbers for general-purpose AN bolts, clevis bolts, and eyebolts, this dash indicates that the bolt is made of carbon steel. With these types of bolts, the letter C, used in place of the dash, means corrosion-resistant steel; the letter D means 2017 aluminum alloy; and the letters DD stand for 2024 aluminum alloy. For some bolts of this type, a letter H is used with these letters or with the dash. If it is so used, the H shows that the bolt has been drilled for safetying.

Next, notice the number 20 that follows the dash. This is called the dash number, and it represents the bolt's grip (as taken from special tables). In this instance the number 20 stands for a bolt that is 2 1/32 inches long.

The last character in the AN number illustrated in figure 6-16 is the letter A. This signifies that the bolt is not drilled for cotter pin safetying. If no letter were used after the dash number, the bolt shank would be drilled for safetying.

NAS PART NUMBER.—Another series of bolts used in aircraft construction is the National Aircraft Standard (NAS). (See fig. 6-17.) In considering one of the NAS bolts, NAS144 (special internal wrenching type), notice that the bolt identification code starts with the letters NAS, which show, of course, that the code represents a National Aircraft Standard piece of hardware. Next, notice that

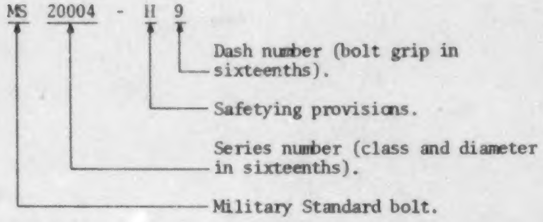

NAS 14 4 - 25
Dash number (bolt grip in sixteenths).
Diameter in sixteenths.
Series number.
National Aircraft Standard bolt.

AM.324

Figure 6-17.—NAS bolt part number breakdown.

the series has a three-digit number, 144. The first two digits (14) show the class of the bolt. The next number (4) indicates the bolt diameter in sixteenths of an inch. The dash number (25) indicates bolt grip in sixteenths.

MS PART NUMBER.—Military Standard (MS) is another series of bolts used in aircraft construction. In considering the part number shown in figure 6-18, the MS indicates that the bolt is a Military Standard bolt. The series number (20004) indicates the bolt class and diameter in sixteenths of an inch (internal wrenching, 1/4-inch diameter). The letter H before the dash number indicates that the bolt has a drilled head for safetying. The dash number (9) indicates the bolt grip in sixteenths of an inch.


MS 20004 - H 9
Dash number (bolt grip in sixteenths).
Safetying provisions.
Series number (class and diameter in sixteenths).
Military Standard bolt.

AM.298

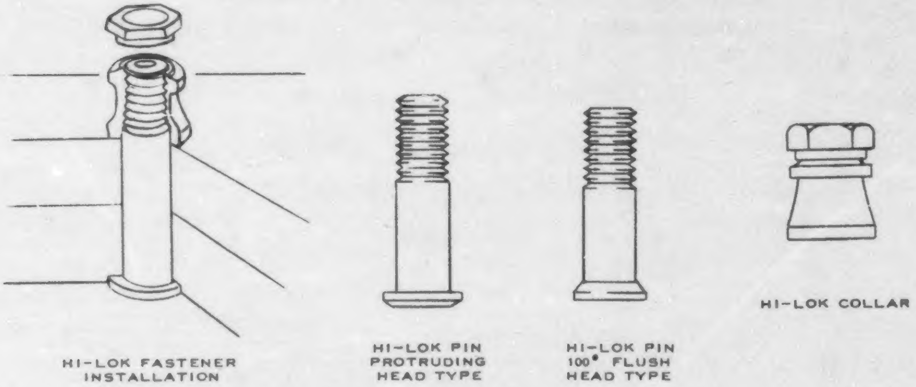
Figure 6-18.—MS bolt part number breakdown.

HI-LOK FASTENERS

The Hi-Lok fastener shown in figure 6-19 combines the features of a rivet and a bolt, and is used for high-strength, interference fit of primary structures. The Hi-Lok fastener consists of a threaded pin and threaded locking collar. The pins are made of cadmium-plated alloy steel with protruding or 100-degree flush heads. Collars for the pins are made of anodized 2024-T6 aluminum or stainless steel. The threaded end of the pin is recessed with a hexagon socket to allow installation from one side. The major diameter of the threaded part of the pin has been truncated (cut undersize) to accomodate a 0.004-inch maximum interference fit. One end of the collar is internally recessed with a 1/16-inch, built-in variation which automatically provides for variable material thickness without the use of washers and without preload changes. The other end of the collar has a torque-off wrenching device which controls a predetermined residual tension of preload (±10%) in the fastener.

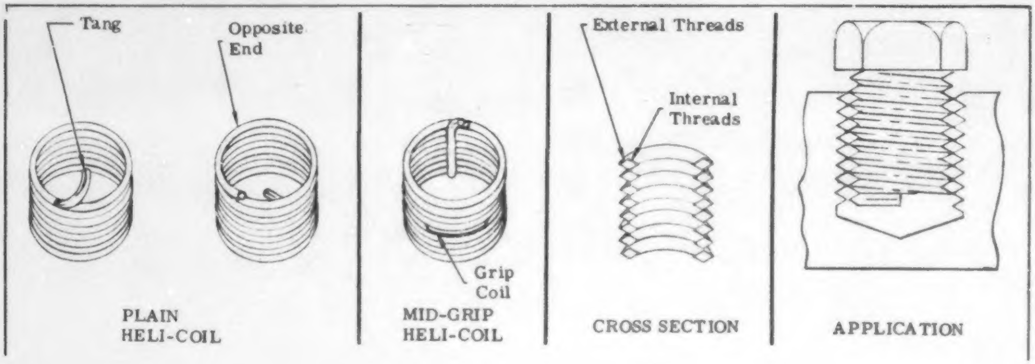
HELI-COIL INSERTS

Heli-Coil thread inserts are primarily designed to be used in materials which are not suitable for threading because of their softness. They are


HI-LOK FASTENER INSTALLATION
HI-LOK PIN PROTRUDING HEAD TYPE
HI-LOK PIN 100° FLUSH HEAD TYPE
HI-LOK COLLAR

AM.325

Figure 6-19.—Hi-Lok fastener.



AM.326

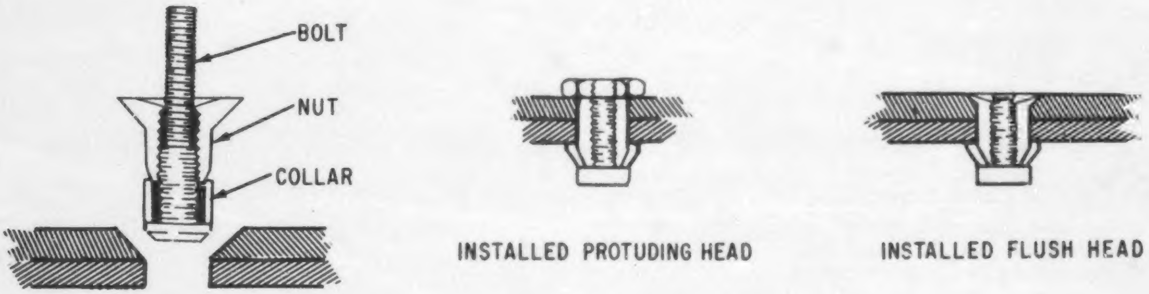
Figure 6-20.—Heli-Coil inserts.

made of a diamond cross-sectioned stainless steel wire which is helically coiled and, in its finished form, is similar to a small spring which has been fully compressed. There are two types of Heli-Coil inserts. (See fig. 6-20.) One is the plain insert, made with a tang that forms a portion of the bottom coil offset, and is used to drive the insert. This tang is left on the insert after installation, except when its removal is necessary to provide clearance for the end of the bolt. The tang is notched to provide for the breakoff from the body of the insert, thereby providing full penetration for the fastener.

The second type of insert used is the self-locking mid-grip insert which has a specially formed grip coil midway of the insert, producing a gripping effect on the engaging screw. For quick identification, the self-locking mid-grip inserts are dyed red.

JO-BOLT FASTENERS

The Jo-Bolt shown in figure 6-21 is a high-strength, blind, structural fastener that is used on difficult riveting jobs when access to one side of the work is impossible. The Jo-Bolt consists of three parts: an aluminum alloy or alloy steel nut, a threaded alloy steel bolt, and a corrosion-resistant steel sleeve, which are factory pre-assembled. The head styles available for Jo-Bolts are the 100-degree flush head, hexagon



AM.327

Figure 6-21.—Jo-Bolts.

protruding head, and the 100-degree flush millable head.

AIRCRAFT NUTS

Aircraft nuts differ in design and material just as bolts do, in that they are designed to do a specific job with the bolt. For instance, some of the nuts are made of cadmium-plated carbon steel, stainless steel, brass, or aluminum alloy. The type of metal used is not identified by markings on the nuts themselves. Instead, the material must be recognized from the metallic luster of the metal.

Nuts also differ greatly in size and shape. In spite of these many and varied differences they all fall under one of two general groups–self locking and nonself-locking. Nuts are further divided into types such as plain nuts, castle nuts, checknuts, plate nuts, channel nuts, barrel nuts, internal wrenching nuts, external wrenching nuts, shear nuts, sheet spring nuts, and wingnuts. Each of these groups is discussed in subsequent paragraphs and sections.

Nonself-Locking Nuts

Nonself-locking nuts require the use of a separate locking device for security of installation. There are several types of these locking devices which are mentioned in the following paragraphs in connection with the nuts on which they are used. Since no single locking device can be used with all types of nonself-locking nuts, the AMS must select one suitable for the type of nut being used. Figure 6-22 illustrates four nonself-locking nuts.

CASTLE NUT.–The castle nut is used in conjunction with drilled-shank bolts, hex-head bolts, clevis bolts, eyebolts, and drilled head studs. It is fairly rugged and can withstand large tensional loads. Slots (called castellations) in the nut are designed to accommodate a cotter pin or lock wire for safetying purposes.

CASTELLATED SHEAR NUT.–The castellated shear nut is designed for use with devices such as drilled clevis bolts and threaded taper pins which are normally subjected to shearing stress only. Like the castle nut, it is castellated for safetying, but is not as deep nor as strong as the castle nut.

PLAIN HEX NUT.–The plain hex nut is of rugged construction. This makes it suitable for carrying large tensional loads. However, since it requires an auxiliary safetying device, such as a checknut or lockwasher, its use on aircraft structures is somewhat limited.

LIGHT HEX NUT.–The light hex nut is a nuch lighter nut than the plain hex nut and must be locked by an auxiliary device. It is used for miscellaneous light-tension requirements.

CHECKNUTS.–The checknut is employed as a locking device for plain nuts, setscrews, threaded rod ends, and other devices.

WINGNUTS.–Wingnuts are intended for places where the desired tightness can be obtained by use of the fingers and where the assembly is frequently removed, such as battery terminal connections. In the illustration, note the hole in one of the wings, which is used for safetying the nut with wire.

Self-Locking Nuts

Self-locking nuts provide tight connections which will not loosen under vibrations. Self-locking nuts approved for use on aircraft meet

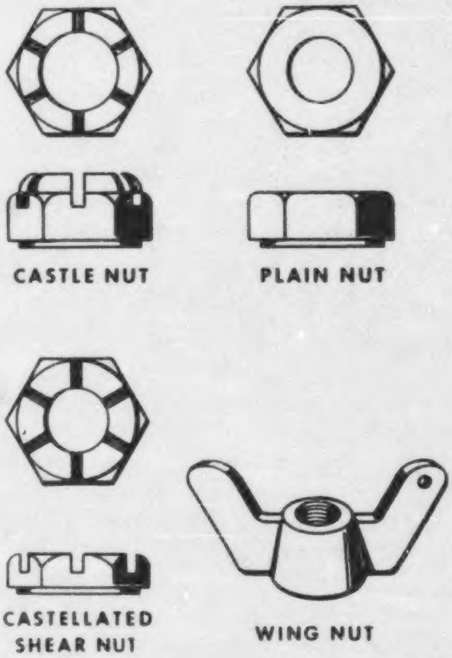


Figure 6-22.–Nonself-locking nuts.

critical specifications as to strength, corrosion resistance, and temperatures. The two general types of self-locking nuts are the all-metal nuts and metal nuts with a nonmetallic insert to provide the locking action. New self-locking nuts must be used each time components are installed in critical areas throughout the entire aircraft, including all flight, engine, and fuel control linkage and attachments. The Boots and the Flexloc are examples of the all-metal type; the Elastic Stop is an example of the nonmetallic insert type. Figure 6-23 shows several types of self-locking nuts.

The Boots self-locking nut is of one-piece all-metal construction, designed to hold tight in spite of severe vibration. It has two sections connected by a spring which is an integral part of the nut. This load-carrying and locking nut is so spaced that the two sets of threads are out of phase—that is, so spaced that a bolt which has been screwed through the load-carrying section must push the locking section outward against the force of the spring in order to engage the threads of the locking section properly. Thus, the spring, through the medium of the locking section, exerts a constant locking force on the bolt in the same direction as a force that tightens the nut. The nut can be removed and used again without impairing its efficiency.

Other types of all-metal self-locking nuts are constructed with the threads in the load-carrying portion of the nut out of phase with the threads in the locking portion, or with a saw cut top portion with a pinched-in thread. The locking action of these types depends upon the resiliency of the metal when the locking section and load-carrying section are forced into alignment when engaged by the bolt or screw threads.

The Elastic Stop nut is constructed with a nonmetallic (nylon) insert which is designed to lock the nut in place. The insert is unthreaded and has a smaller diameter than the nut proper. When a screw or bolt is inserted, contact between the bolt or screw threads and the insert produces the locking action. The Elastic Stop nut is a low-temperature nut and must not be subjected to temperatures above 250° F.

There are certain precautions which must be observed with all self-locking nuts. Bolts, studs, and screws with damaged threads and rough ends must not be used. Bolts, studs, and screws of 1/4 inch or less with cotter pin holes shall not be used with self-locking nuts. Bolts, studs, and screws over 1/4 inch in diameter may be used with self-locking nuts, provided the cotter pin holes are free from burrs.

Used self-locking nuts are generally suitable for reuse in noncritical applications provided the threads have not been damaged and are in a serviceable condition and if the locking material is not damaged or permanently distorted.

NOTE: If any doubt exists about the condition of the nut, replace it with a new one.

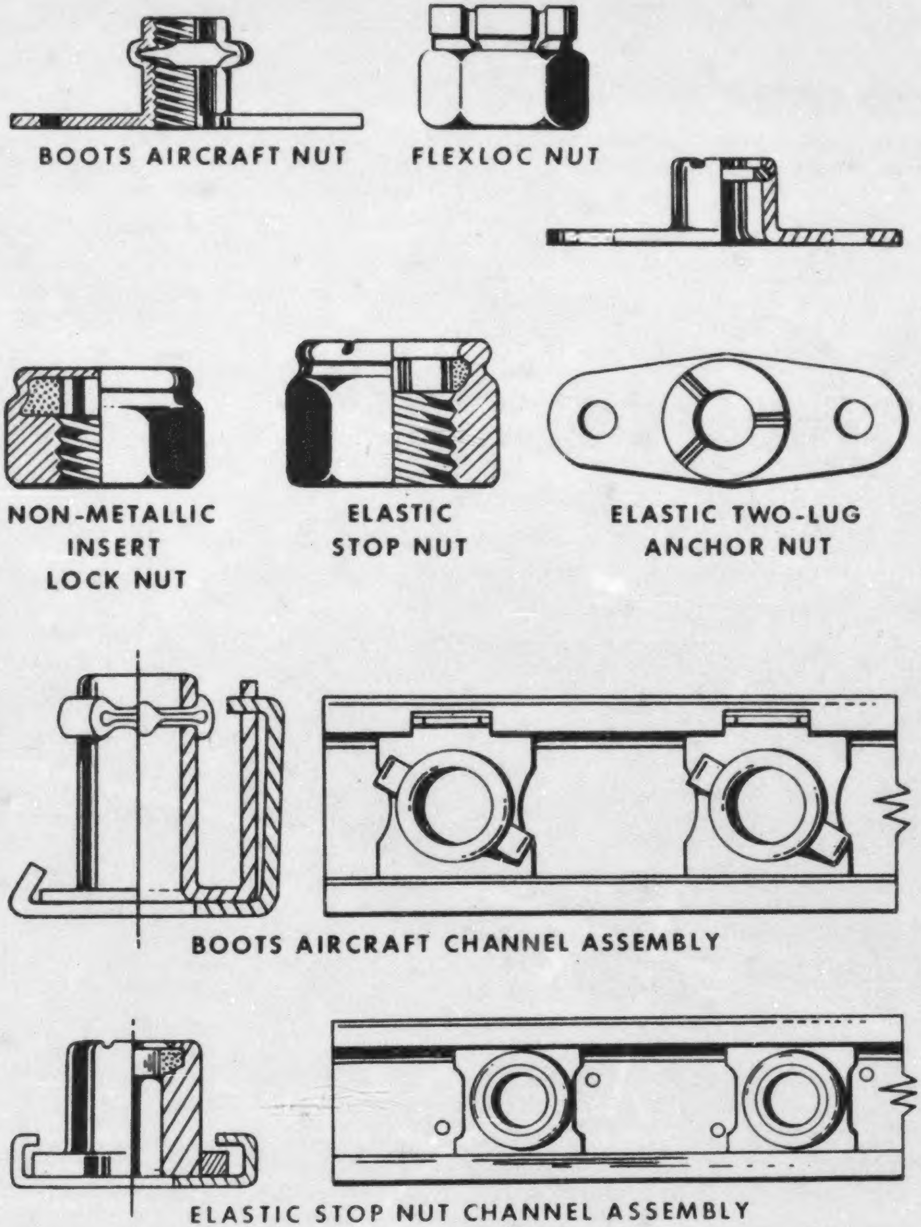
When anchoring lightweight parts the sheet spring nut (fig. 6-24) is used. Applications include supporting line clamps, electrical equipment, small access doors, etc. It is made of sheet spring steel, cut so as to have two flaps. The ends of these flaps are notched to form a hole that is somewhat smaller in diameter than the screw used. The sheet spring nut has a definite arch which tends to flatten out as the screw pulls the flaps in toward the threads. This flattening action forces the flaps of the nut tightly into the threads of the screw, and the springiness of the sheet spring nut pushes upward on the screw threads, binding them and locking the screw in place. With the sheet spring nut, either a standard or a sheet-metal self-tapping screw is used.

WASHERS

Washers used in aircraft structures may be grouped into three general classes—PLAIN washers, LOCKWASHERS, and SPECIAL washers. Figure 6-25 shows some of the most commonly used types.

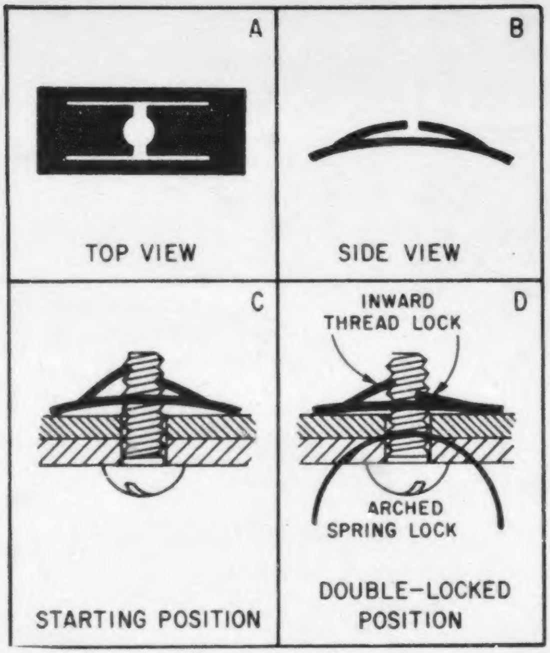
Plain washers are widely used under nuts to provide a smooth bearing surface, to act as a shim in obtaining the correct relationship between the threads of the bolt and the nut, and to adjust the position of castellated nuts with respect to drilled cotter pin holes in bolts. Plain washers are also used under lockwashers to prevent damage to surfaces of soft materials.

Lockwashers are used with plain nuts when self-locking or castellated type nuts are not applicable. Sufficient friction is provided by the


BOOTS AIRCRAFT NUT
FLEXLOC NUT
NON-METALLIC INSERT LOCK NUT
ELASTIC STOP NUT
ELASTIC TWO-LUG ANCHOR NUT
BOOTS AIRCRAFT CHANNEL ASSEMBLY
ELASTIC STOP NUT CHANNEL ASSEMBLY

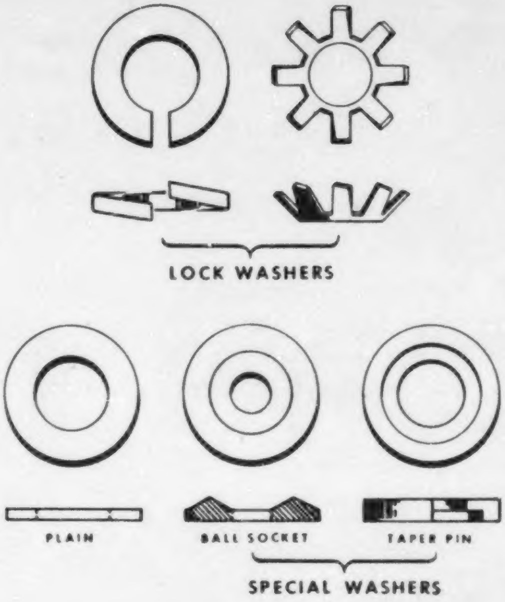
AM.44

Figure 6-23.—Self-locking nuts.



AM.328

Figure 6-24.—Sheet spring nut.



AM.45

Figure 6-25.—Various types of washers.

spring action of the washer to prevent loosening of the nut from vibration. Lockwashers are not to be used on primary structures, secondary structures, or accessories where failure might result in damage or danger to aircraft or personnel.

Special washers, such as ball-socket and seat washers, taper pin washers, and washers for internal-wrenching nuts and bolts, are designed for special applications.

Ball-socket and seat washers are used in applications where the bolt is installed at an angle to the surface, or where perfect alignment with the surface is required at all times. These washers are used together.

Taper pin washers are used in conjunction with threaded taper pins and are installed under the nut to effect adjustment where a plain washer would distort.

Washers for internal-wrenching nuts and bolts are used in conjunction with NAS internal-wrenching bolts. The washer used under the head is countersunk to seat the bolthead/shank radius. A plain washer is used under the nut.

INSTALLATION OF NUTS AND BOLTS

Be certain that each bolt is of correct material. Examine the marking on the head to determine whether a bolt is steel or aluminum alloy.

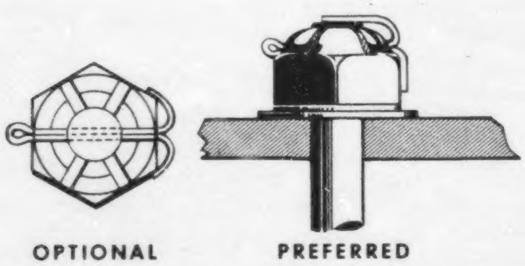
It is of extreme importance to use like bolts in replacement. In every case, refer to the applicable Maintenance Instructions Manual and Illustrated Parts Breakdown.

Be sure that washers are used under both the heads of bolts and nuts unless their omission is specified. A washer guards against mechanical damage to the material being bolted and prevents corrosion of the structural members. An aluminum alloy washer should be used under the head and nut of a steel bolt securing aluminum alloy or magnesium members. Steel washers should be used when joining steel members with steel bolts.

Whenever possible the bolt should be placed with the head on top or in the forward position. This position tends to prevent the bolt from slipping out if the nut is accidentally lost.

SAFETYING OF NUTS

It is very important that all nuts, except the self-locking type, be safetied after installation. This prevents nuts from loosening in flight due to vibration. Figure 6-26 illustrates the proper way to secure a nut using a cotter pin.



AM.43

Figure 6-26.—Cotter pin installation.

APPLICATION OF TORQUE

Torque is the amount of twisting force applied when tightening a nut. If torque values are specified in the appropriate manual, a torque wrench must be used. Regardless of whether torque values are specified or not, it is improtant that all nuts in a particular installation be tightened a like amount. This permits each bolt in a group to carry its share of the load. It is a good practice, therefore, to use a torque wrench in all nut and bolt applications.

SCREWS

Screws are the most common type of threaded fasteners used on aircraft. They are similar to other types of threaded fasteners, such as bolts, but differ mainly in that they usually have a lower material strength, a looser thread fit, and shanks threaded along their entire length. However, several types of structural screws are available which differ from structural bolts only in the type of head; the material is equivalent and there is a difinite grip. Screws may be divided into four main groups—structural screws, machine screws, self-tapping screws, and setscrews.

Structural Screws

Structural screws are used for assembly of structural parts, as are structural bolts. They are made of alloy steel and are properly heat treated. Structural screws have a definite grip length (fig. 6-27) and the same shear and tensile strengths as the equivalent size bolt. They differ from structural bolts only in the type of head. These screws are available in round-head, countersunk-head, and brazier-head types, either slotted or recessed for the various types of screwdrivers.

Machine Screws

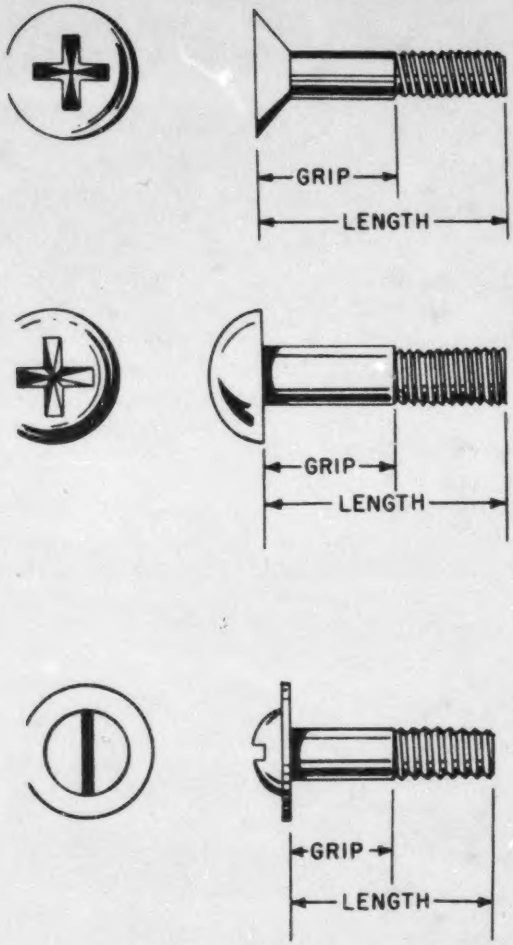
The commonly used machine screws are the round-head, flat-head, fillister-head, pan-head, truss-head, and socket-head types.

FLAT-HEAD MACHINE SCREWS.—Flat-head machine screws are used in countersunk holes where a flush finish is desired. These screws are available in 82 and 100 degrees of head angle and have various types of recesses and slots for driving.

ROUND-HEAD MACHINE SCREWS.—Round-head machine screws are frequently used in assembling highly stressed aircraft components.

FILLISTER-HEAD MACHINE SCREWS.—Fillister-head machine screws are used as general-purpose screws and also may be used as capscrews in light applications such as the attachment of cast aluminum gearbox cover plates.

SOCKET-HEAD MACHINE SCREWS.—Socket-head machine screws are designed to be screwed into tapped holes by internal wrenching. They are used in applications which require high strength precision products, compactness of



AM.329

Figure 6-27.—Structural screws.

the assembled parts, or sinking of heads below surfaces into holes.

PAN-HEAD AND TRUSS-HEAD MACHINE SCREWS.—Pan-head and truss-head screws are general-purpose screws used where head height is unimportant. These screws are available with cross-recessed heads only.

Self-Tapping Screws

A self-tapping screw is one that cuts its own internal threads as it is turned into the hole in which it is inserted. Self-tapping screws can be used only in comparatively soft metals and materials. Self-tapping screws may be further divided into two classes or groups—machine self-tapping screws and sheet-metal self-tapping screws.

Machine self-tapping screws are usually used for attaching removable parts, such as nameplates, to castings. The threads of the screw cut mating threads in the casting after the hole has been predrilled undersize. Sheet-metal self-tapping screws are used for such purposes as temporarily attaching sheet metal in place for riveting and for permanent assembly of nonstructural assemblies, where it is necessary to insert screws in blind applications.

CAUTION: Self-tapping screws should never be used to replace standard screws, nuts, or rivets in the original structure.

Setscrews

Setscrews are used to position and hold in place components such as gears on a shaft. Setscrews are available with many different point styles. They are classified as hexagon-socket and fluted-socket headless setscrews.

MISCELLANEOUS FASTENERS

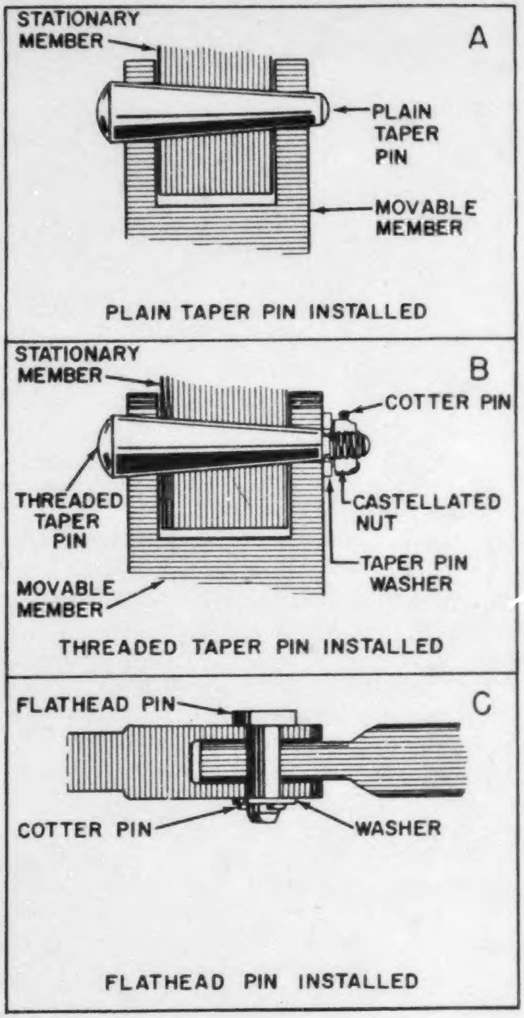
Some fasteners cannot be classified as rivets, turnlocks, or threaded fasteners. Included in this category are taper and flathead pins.

TAPER PINS

Taper pins (fig. 6-28 (A) and (B)) are used in joints that carry shear loads and where the absence of clearance is essential. The threaded taper pin is used with a taper-pin washer and a shear nut if the taper pin is drilled or with a self-locking nut if undrilled. When a shear nut is used with the threaded taper pin and washer, the nut is secured with a cotter pin.

FLATHEAD PINS

The flathead pin is used with tie rod terminals or secondary controls, which do not operate



AM.330

Figure 6-28.–Types of aircraft pins.

continuously. The flathead pin should be secured with a cotter pin. The pin is normally installed with the head up (fig. 6-28 (C)). This precaution is taken to maintain the flathead pin in the installed position in case of cotter pin failure.

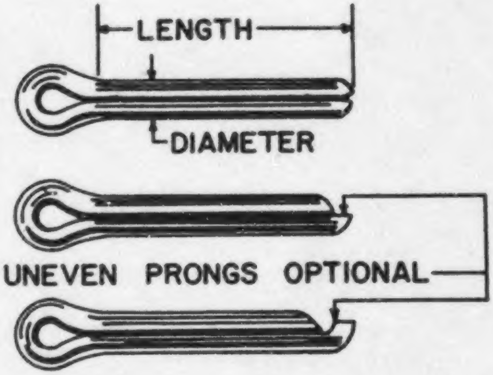
SAFETYING MATERIAL

The AMS will come in contact with many different types of safetying materials. These materials are used to stop rotation and other movement of fasteners, and securing of other equipment likely to come loose due to vibration set up in the aircraft during flight operations.

COTTER PINS

Cotter pins are used to secure bolts, screws, nuts, and pins. Some cotter pins are made of low-carbon steel, while others consist of stainless steel and thus are more resistant to corrosion. In addition, stainless steel cotter pins may be used in locations where nonmagnetic material is required. Regardless of shape or material, all cotter pins are used for the same general purpose–safetying. Figure 6-29 shows three types of cotter pins and how their size is determined.

NOTE: Whenever uneven prong cotter pins are used, the length measurement is to the end of the shortest prong.

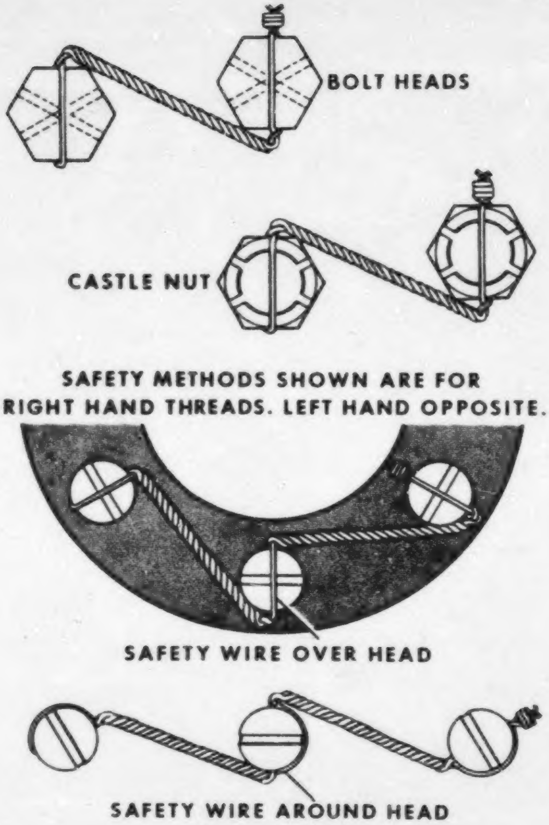


AD.28

Figure 6-29.–Types of cotter pins.

SAFETY WIRE

Safety wire comes in many types and sizes. One must first select the correct type and size of wire for the job. Annealed corrosion-resisting wire is used in high-temperature, electrical-equipment, and aircraft-instrument applications. All nuts except the self-locking types must be safetied; the method used depending upon the


BOLT HEADS
CASTLE NUT
SAFETY METHODS SHOWN ARE FOR
RIGHT HAND THREADS. LEFT HAND OPPOSITE.
SAFETY WIRE OVER HEAD
SAFETY WIRE AROUND HEAD

AM.331

Figure 6-30.—Safety wire installation.

particular installation. Figure 6-30 illustrates the correct methods of installing safety wire. The following general rules apply to safety wiring:

1. All safety wires must be tight after installation, but not under so much tension that normal handling or vibration will break the wire.
2. The wire must be applied so that all pull exerted by the wire tends to tighten the nut.
3. Twists should be tight and even and the wire between nuts as taut as possible without overtwisting. Wire between nuts should be twisted with the hands. The use of pliers will damage the wire. Pliers may be used only for final end twist prior to cutting off excess wire.

Annealed copper safety wire is used for sealing first aid kits, portable fire extinguishers, oxygen regulator emergency valves, and other valves and levers used for emergency operation of aircraft equipment. This wire can be broken by hand in case of an emergency.

CONNECTORS AND COUPLINGS

A variety of clamping devices are utilized in connecting ducting sections to each other or to various components. Whenever lines, components, or ducting are disconnected or removed for any reason, install suitable plugs, caps, or coverings on the openings to prevent the entry of foreign materials. Tag the various parts to insure correct reinstallation. Care should be exercised during handling and installation to insure that flanges are not scratched, distorted, or deformed. Flange surfaces should be free of dirt, grease, and corrosion. The protective flange caps should be left on the ends of the ducting until the installation progresses to the point where removal is necessary to continue with the installation.

In most cases it is mandatory to discard and replace seals and gaskets. Insure that seals and gaskets are properly seated and that mating and alignment of flanges are fitted so that excessive torque is not required to close the joint and impose structural loads on the clamping device. Adjacent support clamps and brackets should remain loose until installation of the coupling has been completed.

FLEXIBLE CONNECTORS/COUPLINGS

Some of the most commonly used plain band couplings are illustrated in figure 6-31. When installing a hose between two duct sections, as illustrated in figure 6-31, the gap between the duct ends should be 1/8 inch minimum to 3/4 inch maximum. When installing the clamps on the connection, the clamp should be 1/4 inch minimum from the end of the connector. Misalignment between the ducting ends should not exceed 1/8 inch maximum.

Marman type clamps commonly used in ducting systems should be tightened to the torque value indicated on the coupling. Tighten all couplings in the manner and to the torque

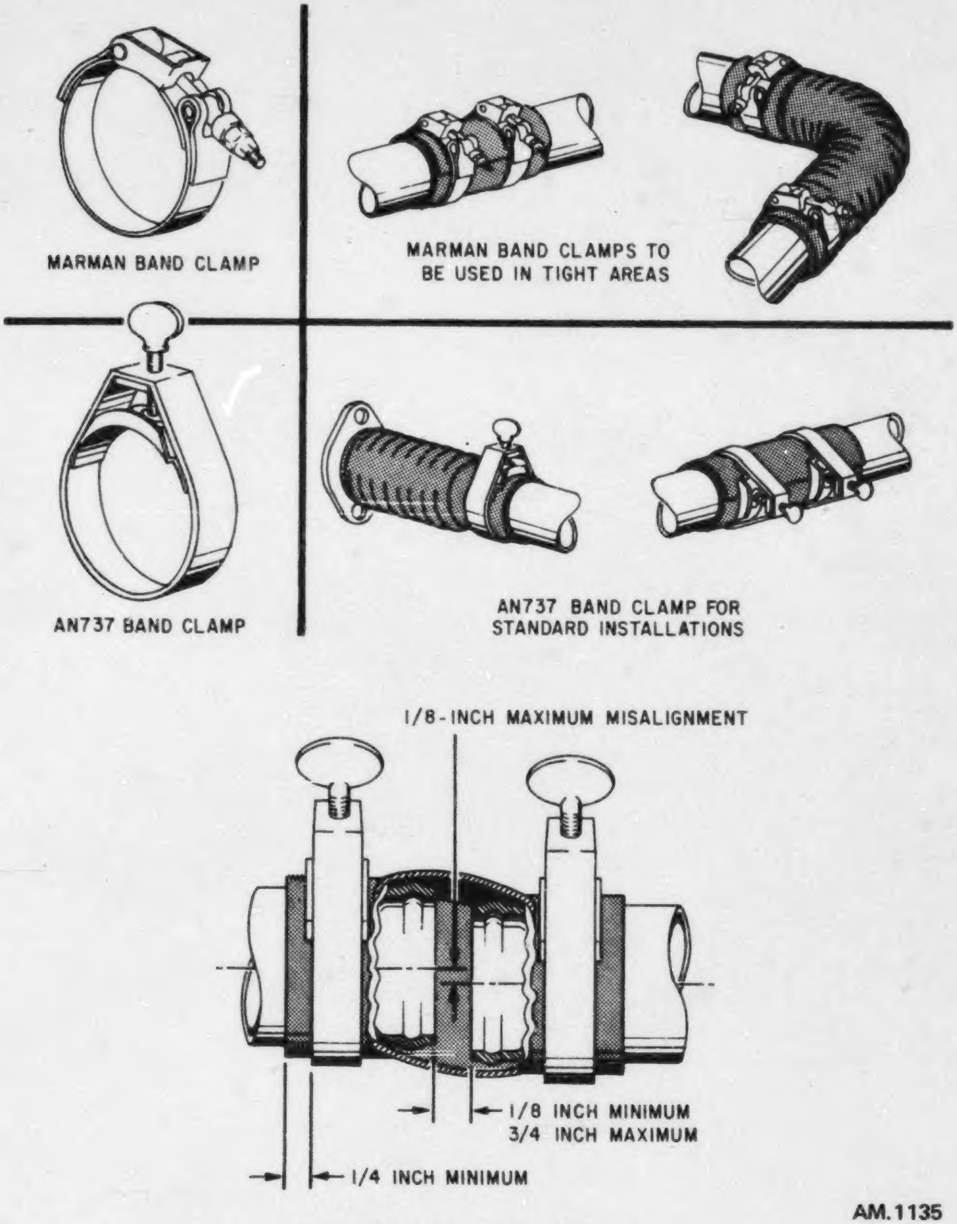

MARMAN BAND CLAMP
MARMAN BAND CLAMPS TO BE USED IN TIGHT AREAS
AN737 BAND CLAMP
AN737 BAND CLAMP FOR STANDARD INSTALLATIONS
1/8-INCH MAXIMUM MISALIGNMENT
1/8 INCH MINIMUM
3/4 INCH MAXIMUM
1/4 INCH MINIMUM
AM.1135

Figure 6-31.—Flexible line connectors.

value as specified on the clamp or in the applicable Maintenance Instructions Manual.

When installing flexible couplings, such as the one illustrated in figure 6-32, the following steps are recommended to assure proper security:

1. Fold back half of the sleeve seal and slip it onto the sleeve.
2. Slide the sleeve (with the sleeve seal partially installed) onto the line.
3. Position the split sleeves over the line beads.

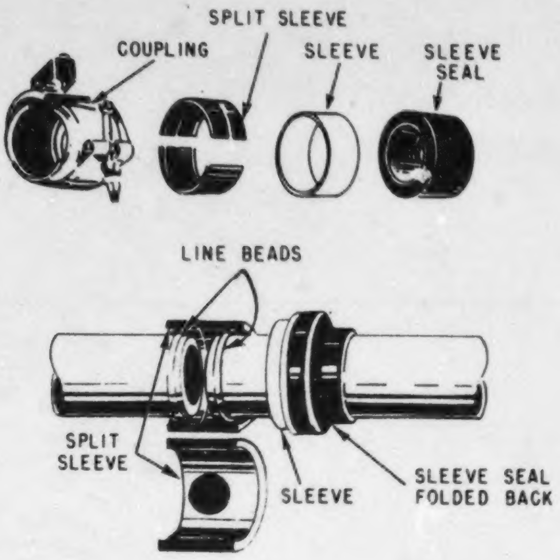


Figure 6-32.—Installation of flexible line couplings.

4. Slide the sleeve over the split sleeves and fold over the sleeve seal so that it covers the entire sleeve.

5. Install the coupling over the sleeve seal and torque to correct value.

NOTE: Torque values for the various sizes and types of couplings may be found by referring to the applicable Maintenance Instructions Manual. Some couplings will have the correct torque value marked on the outside of the band.

RIGID COUPLINGS

The rigid line coupling illustrated in figure 6-33 is referred to as a V-band coupling. When installing this coupling in restricted areas, some of the stiffness of the coupling can be overcome by tightening the coupling over a spare set of flanges and gasket to the recommended torque value of the joint. Tap the coupling a few times with a plastic mallet before removing it.

When installing rigid couplings, follow the steps listed below and illustrated in figure 6-33.

1. Slip the V-band coupling over the flanged tube.
2. Place a gasket into one flange. One quick rotary motion assures positive seating of the gasket.
3. Hold the gasket in place with one hand while the mating flanged tube is assembled into the gasket with a series of vertical and horizontal motions to assure the seating of the mating flange to the gasket.

NOTE: View B of figure 6-33 illustrates the proper fitting and connecting of a rigid coupling, utilizing a metal gasket between the ducting flanges.

4. While holding the joint firmly with one hand, install the V-band coupling over the two flanges.
5. Press the coupling tightly around the flanges with one hand while engaging the latch.
6. Tighten the coupling firmly with a ratchet wrench. Tap the outer periphery of the coupling with a plastic mallet to assure proper alignment of the flanges in the coupling. This will seat the sealing edges of the flanges in the gasket. Tighten again, making sure the recommended torque is not exceeded.
7. Check the torque of the coupling with a torque wrench and tighten until the specified torque is obtained.
8. Safety wire the V-band coupling as illustrated in figure 6-34 as an extra measure of security in the event of T-bolt failure. If the nut on the T-bolt is drilled for safetying, extend the safety wire to the nut so that it will pull on the nut in a clockwise (tightening) direction. Most V-band connectors will utilize a T-bolt with some type of self-locking nut.

MECHANICAL CONTROLS

Included among the responsibilities of the AMS are various mechanical control systems. A mechanical control system may be either a cable type system, push-pull rod system, or a combination of both. Push-pull rod systems are sometimes called "rigid" control systems, but this is not to imply that cable type systems are to be called "flexible" control systems.

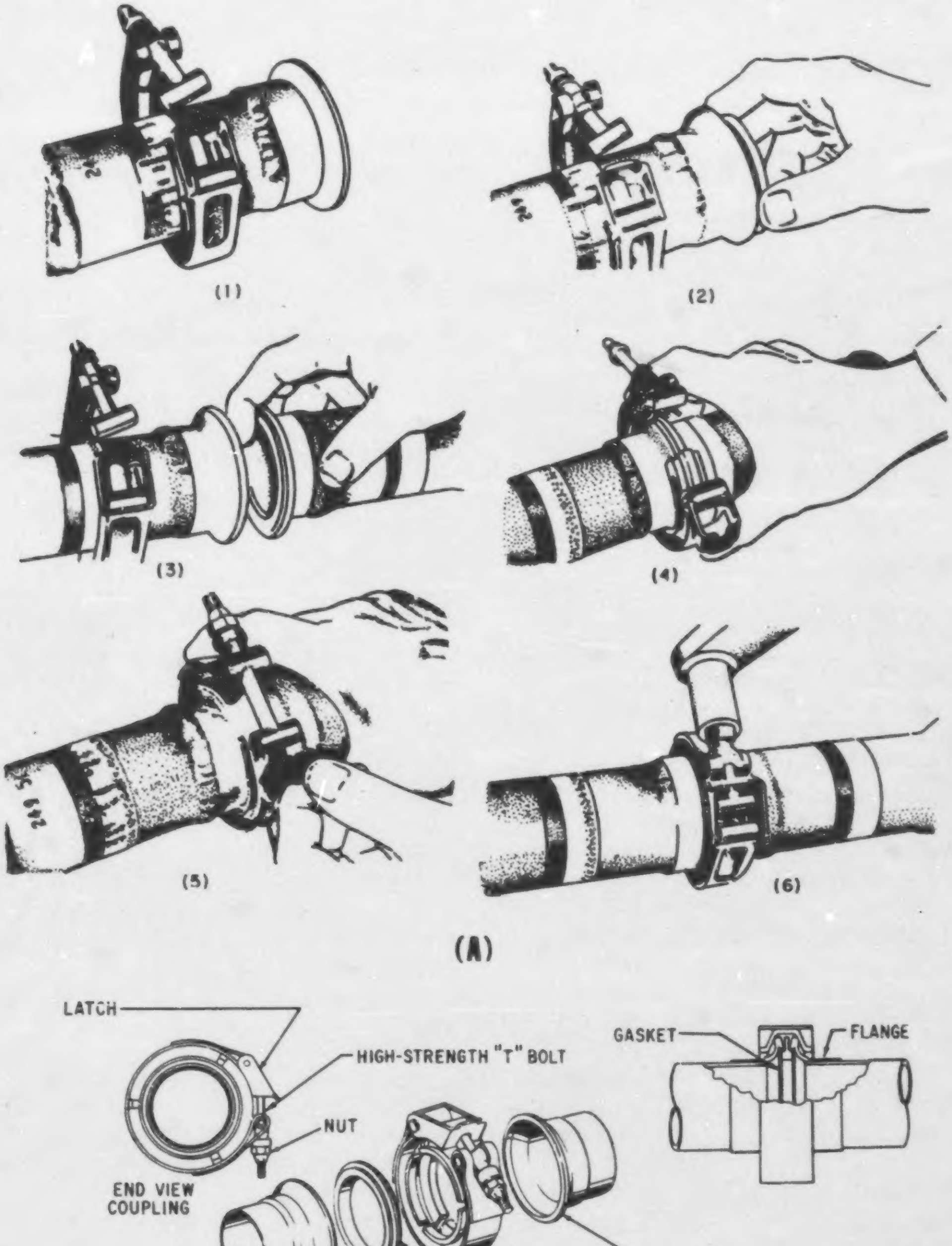
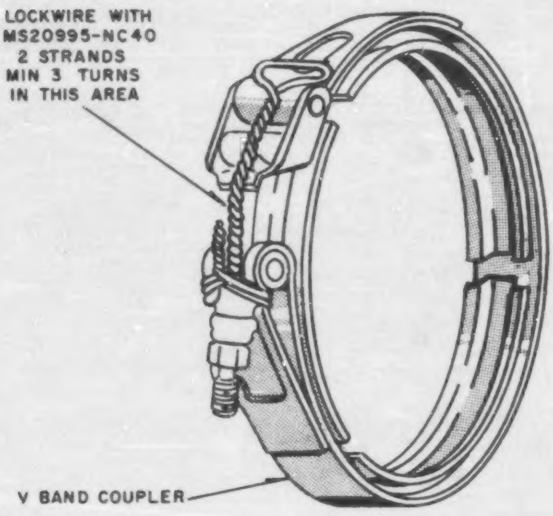


Figure 6-33.—Installation of rigid line couplings.



AM.1137
Figure 6-34.–Safetying a V-band coupling.

CABLE CONTROL SYSTEMS

Cables have many advantages. They will not sever readily under sudden strains such as occur during towing, as of aircraft, trucks, and the like. Cables are stronger than steel rods or tubing of the same size. They flex without setting (permanent deformation) and can be led easily around obstacles by use of pulleys. Cables can be installed over long distances (such as in large aircraft) without a great degree of sagging (or bending), and vibration will not cause them to harden, crystallize, and break, as may be the case with push-pull control rod. Because of the great number of wires used in cables, cable failure is never abrupt, but is progressive over periods of extended use. When used for the manipulation of a unit in a control system, they are usually worked in pairs–one cable to move the unit in one direction, the other to move it in the opposite direction. Yet, in spite of the second cable, weight is saved, because a push-pull rod needed to cause a similar movement in a unit would have to be quite thick and heavy (comparatively speaking). Since cables are used in pairs and are stretched taut, very little play is present in system controls and no lost motion exists between the actuating device and the unit. Consequently, cable-controlled units respond quickly and accurately to cockpit control movement. In some simple cable systems, only one cable is used and a spring provides the return action.

Control Cables

A cable is a group of wires or a group of strands of wires twisted together into a strong wire rope. The wires or strands may be twisted in various ways. The relationship of the direction of twist of each strand to each other and to the cable as a whole is called the lay. The lay of the cable is an important factor in its strength, for if the strands are twisted in a direction opposite to the twist of the strands around the center strand or core, the cable will not stretch (or set) as much as one in which they are all twisted in the same direction. This direction of twist (in opposite direction) is most commonly adopted. Therefore, it is called regular or ordinary lay. Cables may have right regular lay or a left regular lay. If the strands are twisted in the direction of twist around the center strand or core, the lay is called a lang lay. There is a right and left lang lay. The only other twist arrangement, that is, twisting the strands alternately right and left, then twisting them all either to the right or to the left about the core is called a reverse lay. Most aircraft cable has a right regular lay.

When aircraft cables are manufactured, each strand is first formed to the spiral or helical shape to fit the position it is to occupy in the finished cable. The process of such forming is called preforming, and cables made by such a process are said to be preformed. The process of preforming is adopted to secure flexibility in the finished cable and to relieve bending and twisting stresses in the strands as they are woven into the cable. It also keeps the strands from spreading when the cable is cut. All aircraft cable is internally lubricated during construction.

Aircraft control cables are fabricated either from flexible, preformed, carbon-steel wire, or from flexible, preformed, corrosion-resistant steel wire. The smaller corrosion-resistant steel cables are made of steel containing not less than

17 percent chromium and 8 percent nickel while the larger ones (those of the 5/16-, 3/8-, and 7/16-inch diameters) are made of steel which, in addition to the amounts of chromium and nickel just mentioned, also contain not less than 1.75 percent molybdenum.

Cables may be designated 7 x 7, 7 x 19, or 6 x 19 according to their construction. A 7 x 7 cable consists of six strands of seven wires each, laid around a center strand of seven wires. A 7 x 19 cable consists of six strands of 19 wires, laid around a 19-wire central strand. A 6 x 19 IWRC cable consists of six strands of 19 wires each, laid around an independent wire rope center.

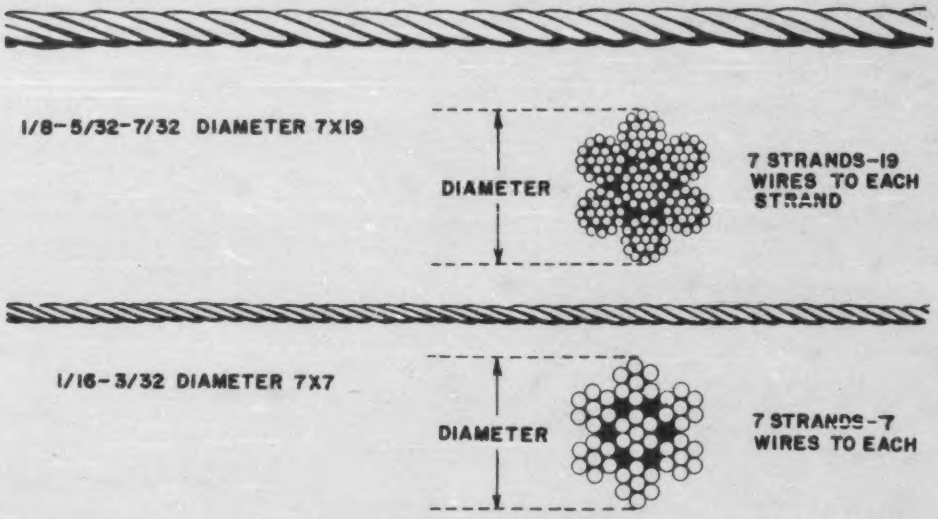
The size of cable is given in terms of diameter measurement. If one speaks of a 1/8-inch cable or a 5/16-inch cable, he means that the cable measures 1/8 inch or 5/16 inch in diameter, measured as shown in figure 6-35. Note that the cable diameter is that of the smallest circle which would enclose the entire cross-section of the cable. Aircraft control cables vary in diameters ranging from 1/16 inch to 3/8 inch.

Cable Fittings

Cable ends may be equipped with several different types of fittings such as terminals, thimbles, bushings and shackles. Terminal fittings are generally of the swaged type. (NOTE: The swaging process is described in detail in chapter 8.) Terminal fittings are available with threaded ends, fork ends, eye ends, single-shank ball, and double-shank ball end.

Threaded ends, fork ends, and eye end terminals are used to connect the cable to turnbuckles, bellcranks, and other linkage in the system. The ball type terminals are used for attaching cable to quadrants and special connections where space is limited. The single-shank ball end is usually used on the ends of cables and the double-shank ball may be used at either the ends or in the center of a cable run. Figure 6-36 illustrates the various types of terminal fittings.

Thimble, bushing, and shackle fittings may be used in place of some types of terminal fittings when facilities and supplies are limited and immediate replacement of the cable is necessary. Figure 6-37 illustrates these fittings.

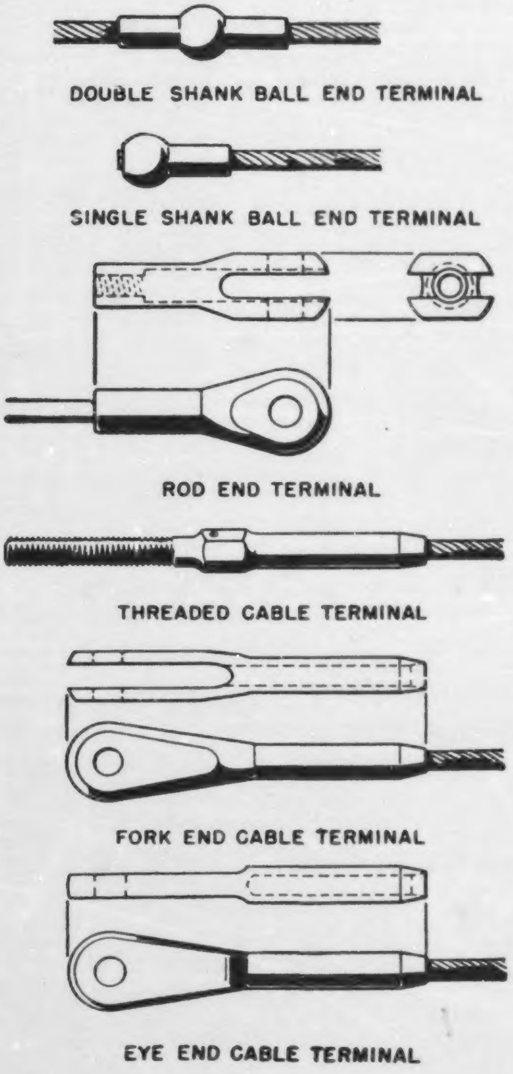

1/8–5/32–7/32 DIAMETER 7X19
DIAMETER
7 STRANDS–19 WIRES TO EACH STRAND
1/16–3/32 DIAMETER 7X7
DIAMETER
7 STRANDS–7 WIRES TO EACH

AM.332

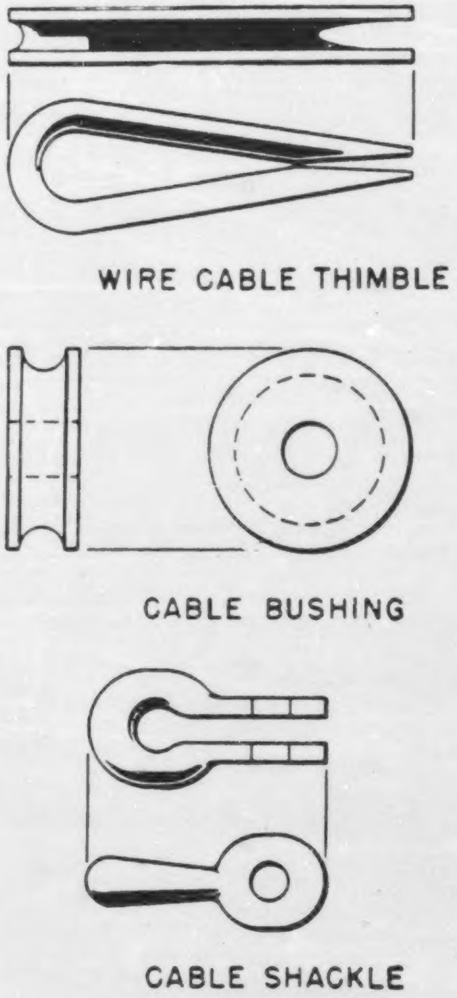
Figure 6-35.—Cable cross sections.

Turnbuckles

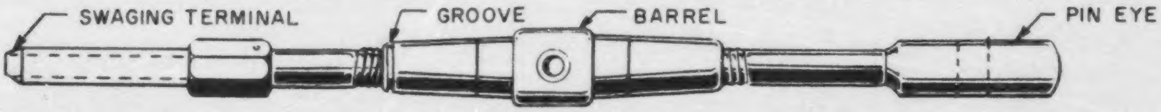
A turnbuckle is a mechanical screw device consisting of two threaded terminals and a threaded barrel. Figure 6-38 illustrates a typical turnbuckle assembly. Turnbuckles are fitted in the cable assembly for the purpose of making minor adjustments in cable length and for adjusting cable tension. One of the terminals has right-hand threads and the other has left-hand threads. The barrel has matching right-and left-hand threads internally. The end of the barrel with left-hand threads inside can usually be identified by either a groove or knurl around



AM.333
Figure 6-36.—Types of terminal fittings.

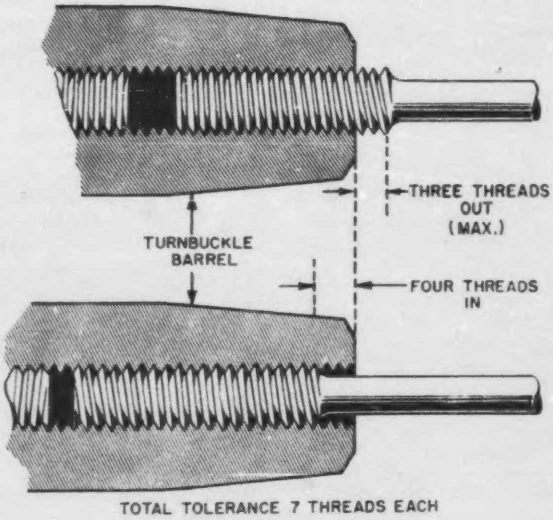


AM.334
Figure 6-37.—Thimble, bushing, and shackle type fittings.



AM.335

Figure 6-38.–Typical turnbuckle assembly.



AM.336

Figure 6-39.–Turnbuckle thread tolerance.

that end of the barrel. Barrels and terminals are available in both long and short lengths.

When installing a turnbuckle in a control system, it is necessary to screw both of the terminals an equal number of turns into the turnbuckle barrel. It is also essential that all turnbuckle terminals be screwed into the barrel at least until not more than three threads are exposed. On initial installation, the turnbuckle terminals should not be screwed inside the turnbuckle barrel more than four threads. Figure 6-39 illustrates turnbuckle thread tolerances.

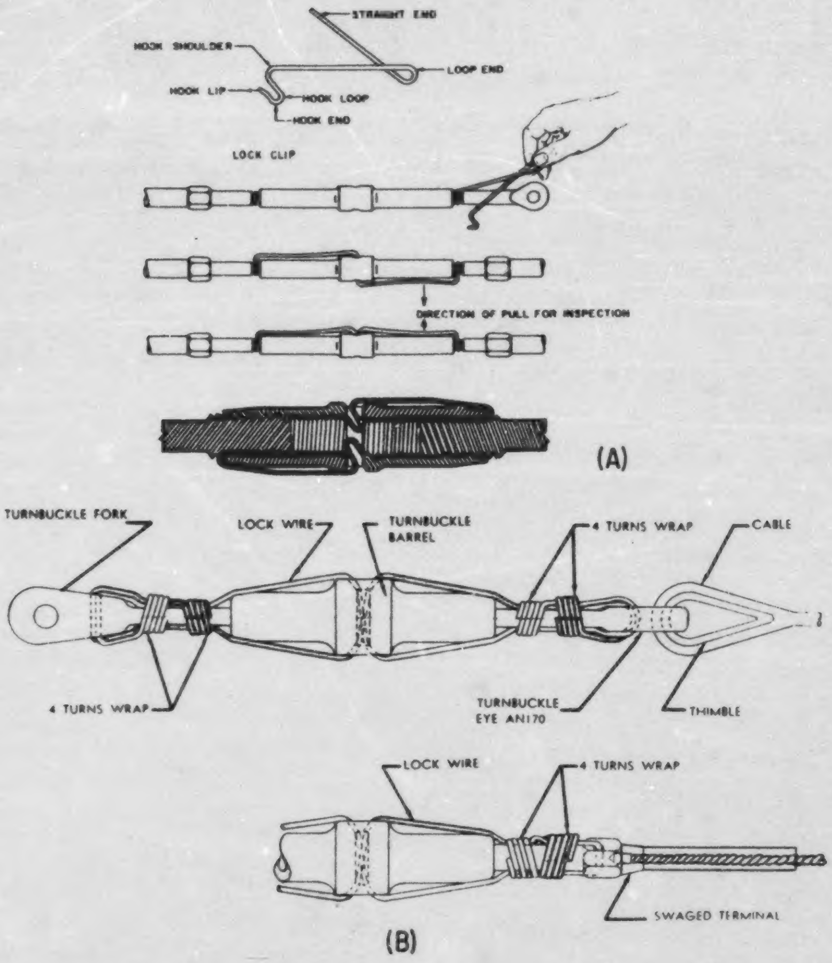
After a turnbuckle is properly adjusted, it must be safetied. There are several methods of safetying turnbuckles. However, only two methods have been adopted as standard procedures by the services. These methods are illustrated in figure 6-40. The preferred method is the clip-locking method shown in (A). The wire-wrapping method shown in (B) is obsolete and should be employed only where facilities will not permit the use of the clip locking method.

Adjustable Connector Links

An adjustable connector link consists of two or three metal strips with holes so arranged that they may be matched and secured with a clevis bolt to adjust the length of the connector. They are installed in cable assemblies for the purpose of making major adjustments in cable length and to compensate for cable stretch. Adjustable connector links are used most often in very long cable assemblies.

Quick Disconnects

Quick disconnects are used in cable systems that may require frequent disconnecting. One type of quick disconnect is made with steel balls swaged to the ends of the cable and which are slipped into a slotted bar and secured with spring-loaded sleeves on each end of the bar. Figure 6-41 illustrates the procedure for disconnecting and connecting this type of quick-disconnect fitting.



AM.337

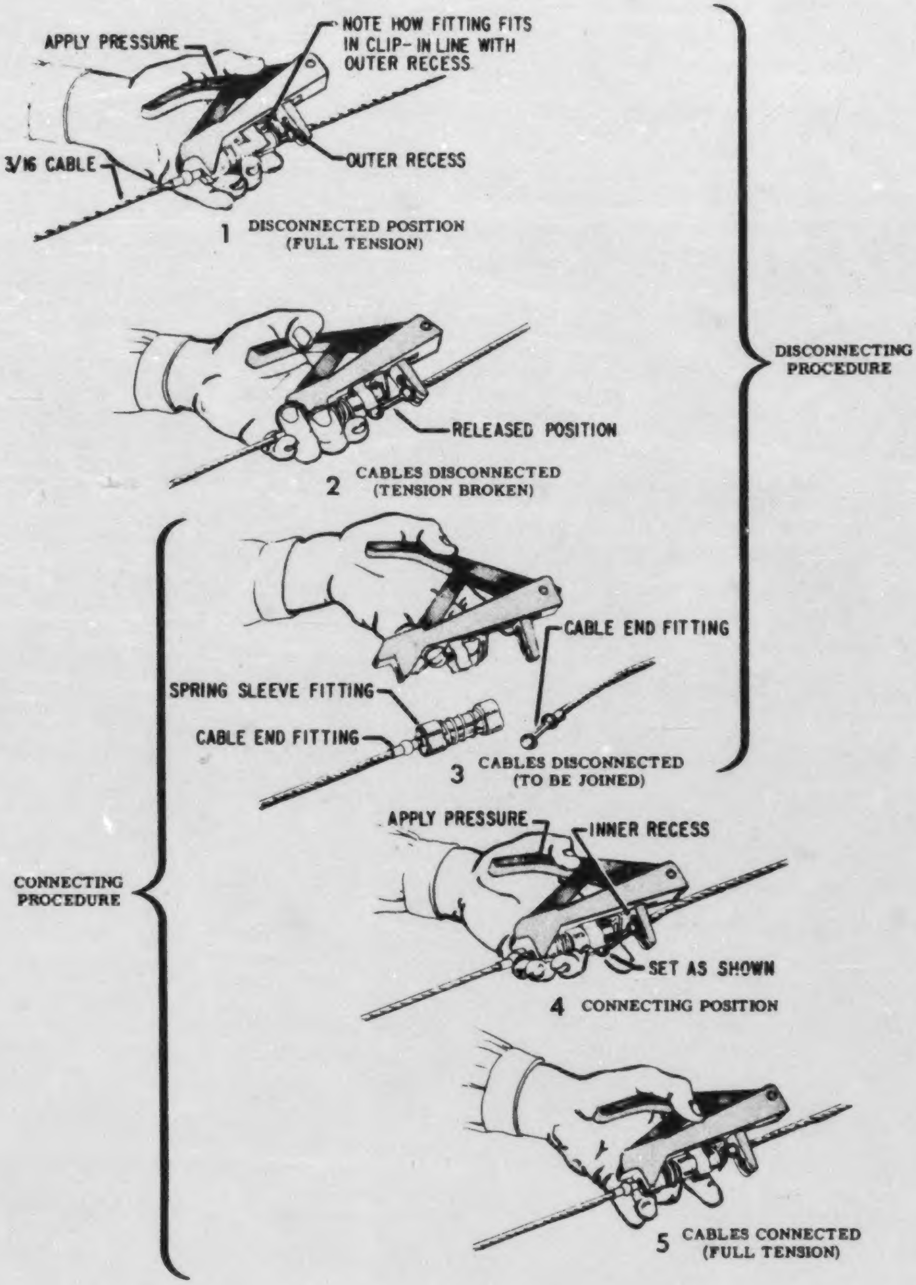
Figure 6-40.—Safetying turnbuckles. (A) Preferred method; (B) wire-wrapping method.

Cables Guides

Fairleads, rubstrips, grommets, pressure seals, and pulleys are all types of cable guides. They are used to protect control cables by preventing the cables from rubbing against nearby metal parts. They are also used as supports to reduce cable vibration in long stretches (runs) of cable. Figure 6-42 shows some typical cable guides.

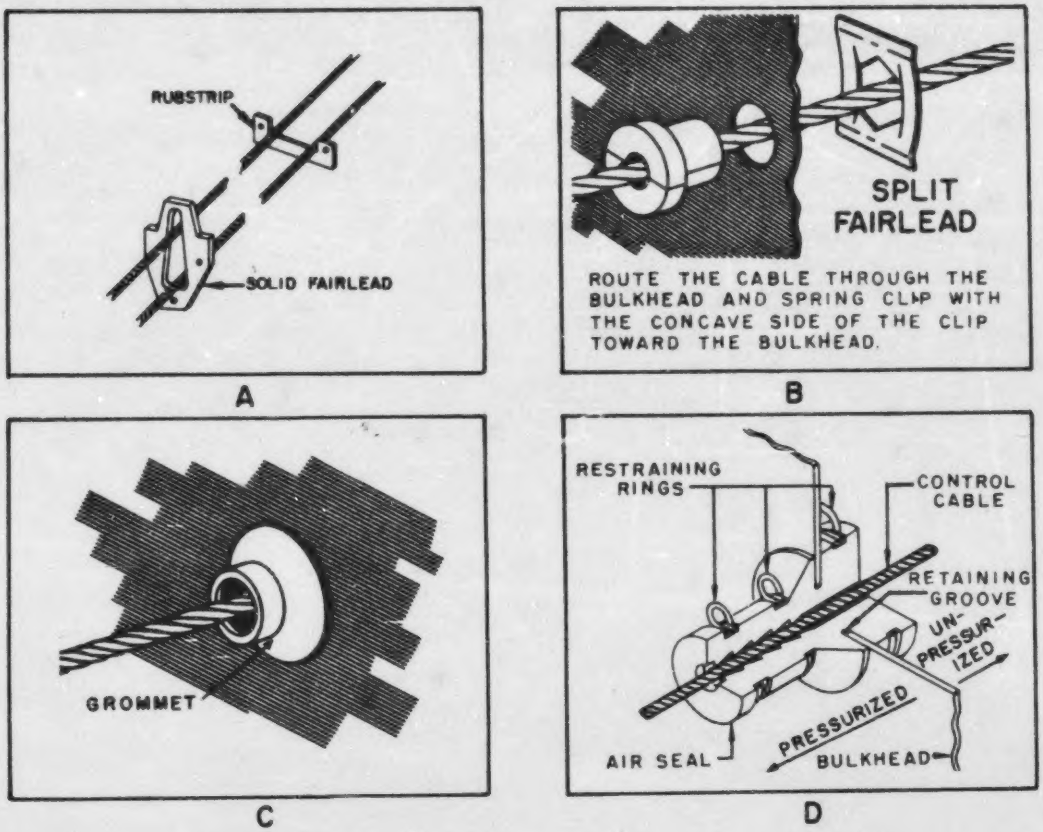
FAIRLEADS.—Fairleads may be made of a solid piece of material to completely encircle cables when they pass through holes in bulkheads or other metal parts (See fig. 6-42.) This type also may be used to reduce cable whipping and vibration in long runs of cable. In the same figure is a rubstrip, which protects cable along one side from rubbing against metal edges.

Split fairleads are made for easy installation



AM.338

Figure 6-41.–Quick-disconnect procedure.



ROUTE THE CABLE THROUGH THE BULKHEAD AND SPRING CLIP WITH THE CONCAVE SIDE OF THE CLIP TOWARD THE BULKHEAD.

AM.339

Figure 6-42.–Typical cable guides.

around single cables to protect them from rubbing on the edges of holes.

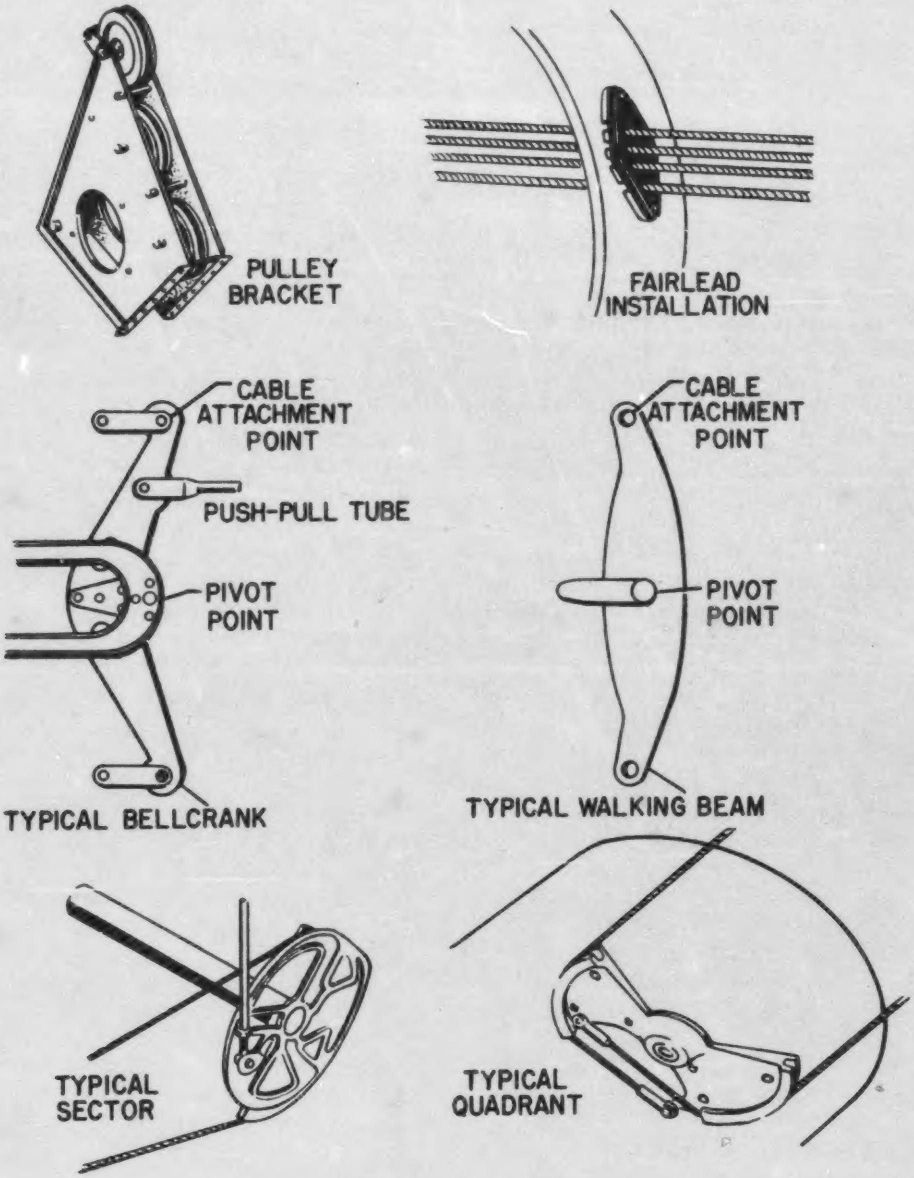
GROMMETS.–Grommets are made of rubber for use on small openings where single cables pass through the walls of unpressurized compartments.

PRESSURE SEALS.–Pressure seals are used on cables or rods which must move through pressurized bulkheads. They fit tightly enough to prevent air pressure loss but not so tightly as to hinder movement of the unit.

Pulleys

Pulleys (or sheaves) are grooved wheels used to change cable direction and to allow the cable to move with a minimum of friction. Most pulleys used on aircraft are made from layers of cloth impregnated with phenolic resin and fused together under elevated temperatures and pressures. Aircraft pulleys are extremely strong and durable and cause a minimum of wear on the cable passing over them. Pulleys are provided with grease-sealed bearings and usually do not require further lubrication. However, pulley bearings may be pressed out, cleaned, and relubricated with special equipment. This is usually accomplished only by Depot level maintenance activities.

Pulley brackets (fig. 6-43), made of sheet or cast aluminum, are required with each pulley installed in the aircraft. In addition to holding



AM.340

Figure 6-43.—Control system components.

the pulley in the correct position and at the correct angle, the brakets provide a guard to prevent the cable from slipping out of the groove on the pulley wheel.

Sectors and Quadrants

These units are generally constructed in the form of an arc or in a complete circular form.

They are grooved around the outer circumference to receive the cable, as shown in figure 6-43. The names sector and quadrant are used interchangeably. Sectors and quadrants are similar to bellcranks and walking beams which are used for the same purpose in rigid control systems.

RIGID CONTROL SYSTEMS

Rigid control systems transfer useful movement through a system of push-pull rods, bellcranks, walking beams, idler arms, and bungees. The simplest rigid control system may consist of push-pull rods and bellcranks only.

Push-Pull Rods

Push-pull rods are rigid rods equipped with eye fittings at each end or with a clevis fitting at one end and an eye fitting at the other. The eyes contain a pressed-in bearing. The rods are generally hollow, and they neck down to a smaller diameter at each end where the fittings are attached. One or both of the fittings are screwed into the necked portion of the rod and are held in place by locknuts and are therefore adjustable. When only one stem is adjustable the stem of the other eye fitting is riveted into the neck at its end of the rod. A hole is drilled into the threaded necks of the push-pull rods for inspection to insure that the stem has engaged a safe number of threads. The stem must be visible through the hole. Push-pull rods are generally made in short lengths to prevent bending under compression loads and vibration.

Bellcranks and Walking Beams

Bellcranks and walking beams are levers used in rigid control systems to gain mechanical advantage and to change the direction of motion in the system when parts of the airframe structure do not permit a straight run. They are often used in push-pull tube systems to decrease the length of the individual tubes and thus add rigidity to the system.

A bellcrank has two arms which form an angle of less than 180 degrees, with a pivot point where the two arms meet. The walking beam is a straight beam with a pivot point in the center. Examples of a bellcrank and a walking beam are also shown in figure 6-43. The two are so similar in construction and use that the names bellcrank and walking beam are often used interchangeably.

Bellcranks and walking beams are mounted in the structure in much the same way as pulley assemblies. Brackets or the structure itself may be used as the point of attachment for the shaft or bolt on which the unit is mounted.

Idler Arms

Idler arms are levers with one end attached to the aircraft structure so it will pivot, and the other end is attached to the push-pull tubes. Idler arms are used to support push-pull tubes and guide them through holes in structural members.

Bungee

Bungees are tension devices used in some rigid systems that are subject to a degree of shock or overloading. They are similar to push-pull rods and perform essentially the same function except that one of the fittings is spring loaded in one or both directions. That is, a load may press so hard in compression against the fittings that the bungee spring will yield and take up the load, thus protecting the rest of the rigid system against damage. The internal spring may also be mounted so as to resist tension rather than compression. An internal double-spring arrangement will result in a bungee that protects against both overtension and overcompression.

CHAPTER 7

AIRCRAFT DAMAGE REPAIR

DAMAGE REPAIR PROCEDURES

In the modern age of high-speed aircraft, the AMS must be familiar with the principle of streamlining and fairing; also, the behavior of various metals in high-velocity air currents and torsional stresses encountered during high-speed flying and maneuvering. One of the most important jobs the AMS will encounter is the repair of damaged skin. All repairs must be of the highest quality and must conform to certain requirements and specifications.

Methods of repairing the structure of a damaged aircraft are given in the Structural Repair Manual for the specific aircraft. No one set of repair rules will apply to all aircraft. The problem of repairing a damaged section is usually solved by duplicating the original part in strength, using the materials and procedures specified in the aircraft Structural Repair Manual.

PREINSPECTION OF DAMAGED AREAS

When any part of the airframe has been damaged, the first step is to clean off all grease, dirt, and paint in the vicinity of the damage so that the extent of the damage may be determined. The adjacent structure must be inspected to determine what secondary damage may have resulted from the transmission of the load or loads which caused the initial damage. Thoroughly inspect the adjacent structures for dents, scratches, abrasions, punctures, cracks, loose seams, and distortions. Check all bolted fittings which may have been damaged or loosened by the load which caused the damage to the structure.

CLASSIFICATION OF DAMAGES

The Structural Repair Manual normally specifies the type of repair to be made to a damaged structure. Damages can normally be classified under one of the following classifications: negligible damage, damage repairable by patching, damage repairable by insertion, and damage necessitating replacement. (See fig. 7-1.) The AMS must decide, after preinspection of the damaged area, on one of the four classifications.

Negligible Damage

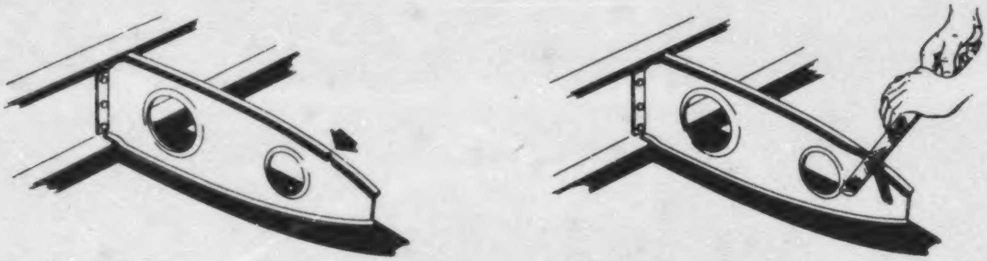
Negligible damage is damage or distortion that can be permitted to exist or can be corrected by a simple procedure. Frequently, negligible damage can be repaired by stop drilling cracks, removing dents, and fabricating temporary fabric patches without placing any restrictions on the aircraft.

Damage Repairable by Patching

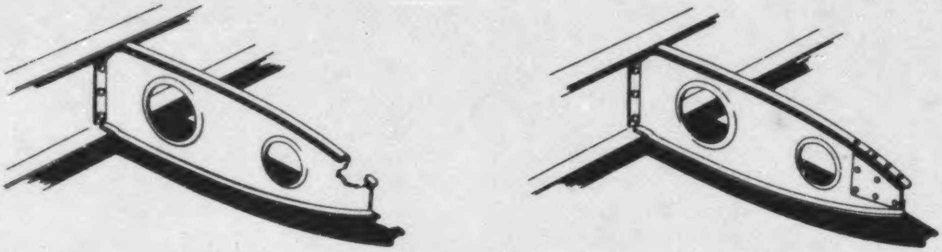
Damage which exceeds negligible damage limits should be investigated to determine the possibility of using a patch repair. A patch repair is made by adding material around the damaged area to enable the damaged structure to carry its designed load.

Damage Repairable by Insertion

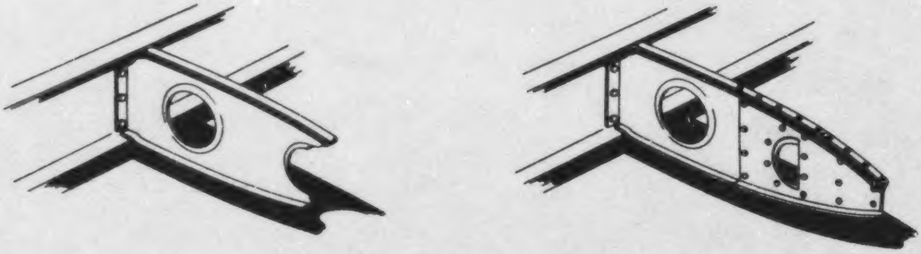
This repair involves the removal of the damaged portion of a member and replacing this portion with materials identical in shape and strength to the damaged member. A backup plate (doubler) is used with this type of repair to



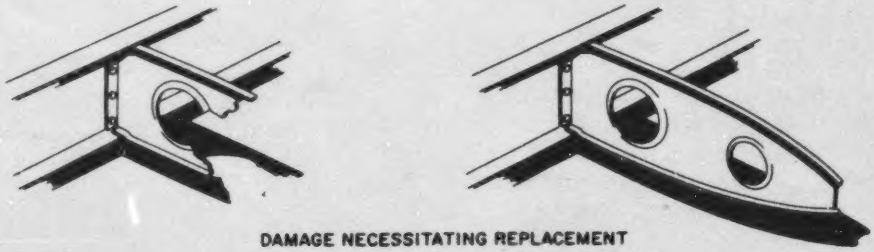
NEGLIGIBLE DAMAGE



DAMAGE REPAIRABLE BY PATCHING



DAMAGE REPAIRABLE BY INSERTION



DAMAGE NECESSITATING REPLACEMENT

AM.341

Figure 7-1.—Classification of damages.

reinforce the damaged area and provide a surface to fasten the filler. This repair is used where a flat surface is required.

Damage Necessitating Replacement

Damage which cannot be repaired by any practical means is classified as damage necessitating replacement.

SELECTION OF REPAIR MATERIAL

The major requirement in making a repair is the duplication of strength of the original structure. The Structural Repair Manual for the aircraft concerned must be consulted for the alloy thickness, and temper designation of the repair material to be used. This manual will also designate the type and spacing of rivets or fasteners to be used in the repair.

In some instances, substitution of materials are allowed. For example, the P-3 Structural Repair Manual specifies that 2024-T42 clad material may be substituted for 2024-T3 clad materials in fuselage areas having sharp or double curvatures. When making a substitution of materials, and conflicting information between manuals exists, the Structural Repair Manual for the aircraft being repaired should be used.

When using the Structural Repair Manual, the AMS normally has several steps to take in finding the correct repair materials and procedures. Figure 7-2 illustrates each of the steps, and are listed in the procedures to follow.

NOTE: The P-3 Structural Repair Manual was selected as a typical manual. The procedures that follow are typical, but are not standard. Various manufacturers use different methods to indicate the types of materials used and special instructions for using their particular manual.

1. The extent of the damage to the aircraft is determined by the preinspection of the damaged area as previously explained.
2. Using a master index diagram, identify the damaged group of the aircraft. From the table shown on the diagram, determine the section of the manual where the component is found.
3. After locating the correct group master index diagram, obtain the correct item number from the illustration for the damaged component.
4. From the component diagram, find the index number/numbers for the damaged unit/units.
5. The index number/numbers are then matched with the item number/numbers on the repair material chart. This chart will normally give the parts description, drawing number, gage, type of material, and location of repair diagram.
6. The repair diagram is found by locating the required section of the manual and turning to the correct figure in that section. Access provisions and negligible damage information are given on the repair diagrams. After the damage has been cleaned up, determine whether or not the damage is negligible in accordance with the repair diagram. If the damage is within the limits of negligible damage, it may be disregarded unless it is necessary to close the hole for aerodynamic smoothness or sealing purposes. If the damage exceeds the limits of negligible damage, it must be repaired in accordance with the repair diagram or replaced.

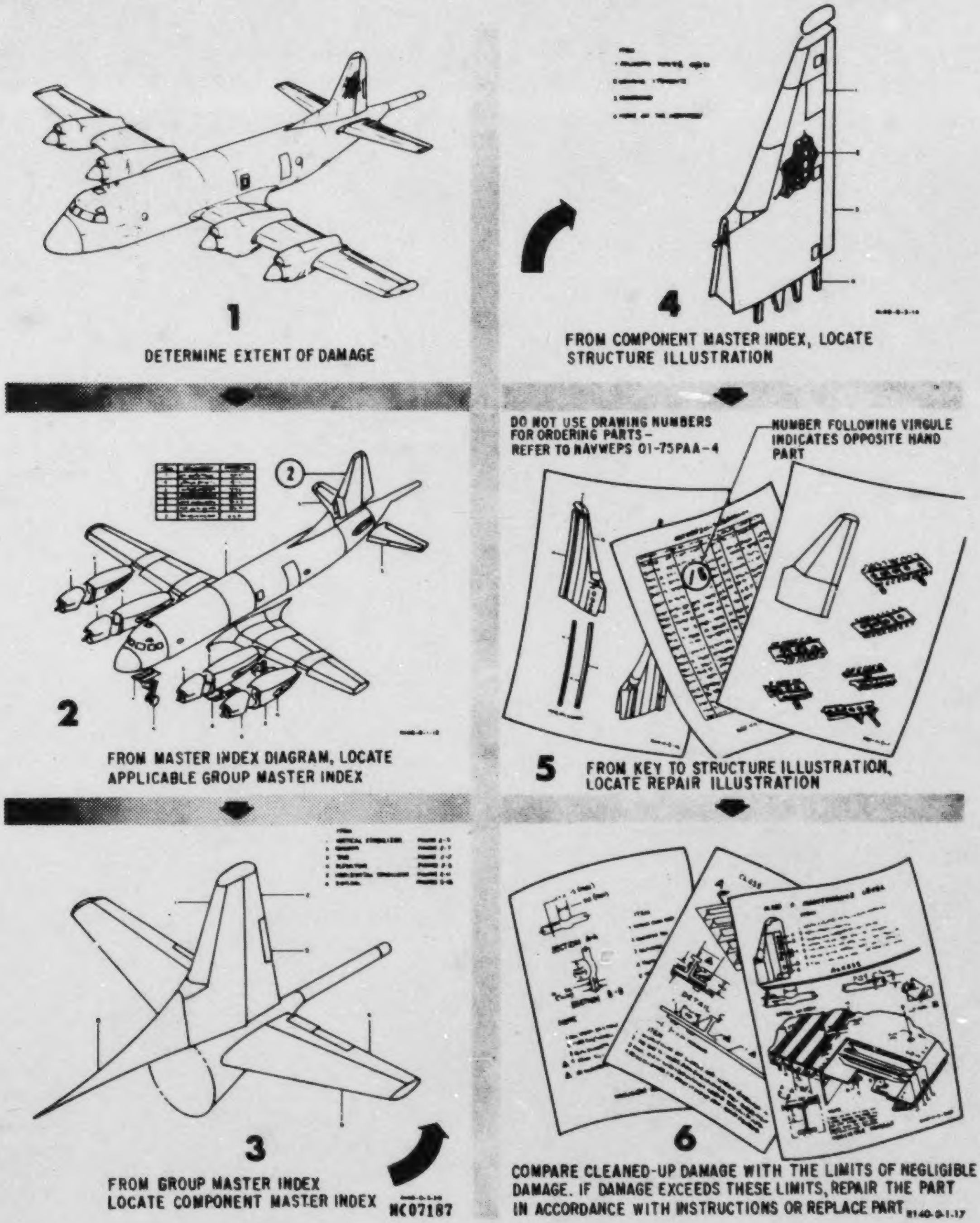
LAYOUT FOR REPAIR

All repairs must be laid out to the given dimensions or by using the damaged part as a pattern. Care should be exercised to avoid scratching the repair material, except where cutting the material is desired. Scratches may develop into cracks and cracks into structural failures. All marks on repair materials, other than cut lines, should be made with a pencil.

SKIN REPAIRS

Skin repair patches may be divided into two general types, the LAP PATCH and the FLUSH PATCH. A brief description of both types of patches follows.

A lap patch is an external patch that has the edges of the patch and the skin overlapping each other. The overlapping portion of the patch is riveted to the skin. On some aircraft, lap patches are permitted in certain areas, but only where aerodynamic smoothness is not important.


1
DETERMINE EXTENT OF DAMAGE
2
FROM MASTER INDEX DIAGRAM, LOCATE APPLICABLE GROUP MASTER INDEX
3
FROM GROUP MASTER INDEX LOCATE COMPONENT MASTER INDEX
NC07187
4
FROM COMPONENT MASTER INDEX, LOCATE STRUCTURE ILLUSTRATION
DO NOT USE DRAWING NUMBERS FOR ORDERING PARTS–REFER TO NAVWEPS 01-75PAA-4
NUMBER FOLLOWING VIRGULE INDICATES OPPOSITE HAND PART
5
FROM KEY TO STRUCTURE ILLUSTRATION, LOCATE REPAIR ILLUSTRATION
6
COMPARE CLEANED-UP DAMAGE WITH THE LIMITS OF NEGLIGIBLE DAMAGE. IF DAMAGE EXCEEDS THESE LIMITS, REPAIR THE PART IN ACCORDANCE WITH INSTRUCTIONS OR REPLACE PART
8140-0-1.17

AM.342

Figure 7-2.—How to use a Structural Repair Manual.

A flush patch consists of a filler patch which is flush with the skin when inserted. It is backed up and riveted to a reinforcement plate which, in turn, is riveted to the inside of the skin. This reinforcement plate is usually referred to, on some repair diagrams, as the doubler, or backup plate. On some high performance aircraft, only the flush patch is permitted in making skin repairs.

OPEN AND CLOSED SKIN AREAS

One of the factors which determine the exact procedure to be used in making skin repairs is the accessibility to the damaged area. Much of the skin on an aircraft is inaccessible from the inside for making repairs. The skin in such areas is referred to as CLOSED SKIN. Skin that is accessible from both sides is called OPEN SKIN.

Repairs to open skin may usually be made in the conventional manner, using specified types of standard rivets, but in repairing closed skin, some type of special blind fasteners must be used. The exact type of fastener used will depend upon the type of repair made and the recommendations of the aircraft manufacturer.

Another of the important factors to be considered when making a skin repair is the stress intensity of the damaged panel. For example, certain skin areas are classified as highly critical, other areas as semicritical, while still other areas may be classified as noncritical. Repairs to damages in highly critical areas must provide 100 percent strength replacement; semicritical areas require 80 percent strength replacement; and noncritical areas require 60 percent strength replacement. When a repair specifies it must provide 60 percent strength replacement, this indicates the amount of repair strength necessary to maintain a margin of safety in skin areas. The 60 percent stress intensity repair is specified when production methods and stiffening requirements have resulted in an overstrength skin with a high margin of safety. This repair provides strength and stiffness equivalent to specific design requirements rather than the original structure of the material. The 100 percent stress intensity repair makes the strength of the repaired skin equal to, or greater than, the original undamaged skin. This type of skin usually has a low margin of safety.

Lap Patches

Lap patches may be installed in areas where aerodynamic smoothness is not important. In areas where it is permitted, the lap patch may be used in repairing cracks as well as small holes.

In repairing cracks, always drill a small hole, (normally called stop drilling), in each end of the crack before applying the patch. This is normally done by using a No. 30 or 40 drill bit. This prevents the concentration of stresses at the apex of the crack and distributes the stresses around the circumference of the hole. The patch must be large enough to install the required number of rivets as determined from the rivet schedule indicated for the gage material in the area which is damaged. (See fig. 7-3.) The recommended patch may be cut circular, square, rectangular, or diamond shaped. The edges are normally chamfered (beveled) to an angle of 45 degrees, for approximately one-half its thickness.

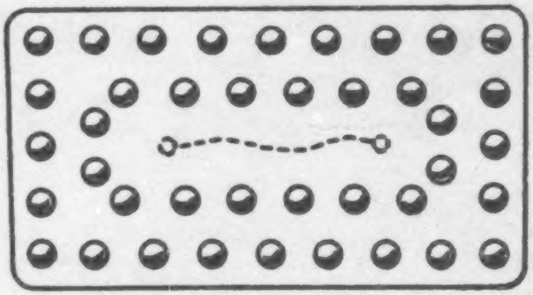
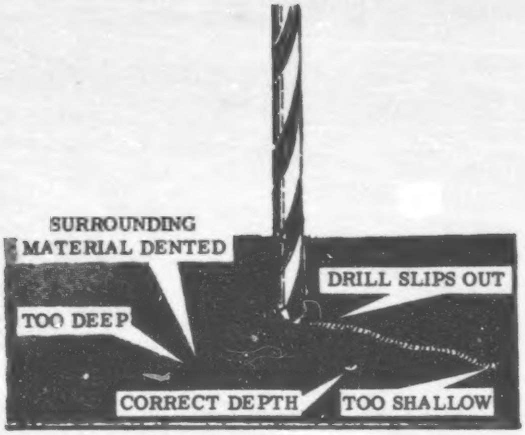

AM.343

Figure 7-3.—Lap patch for repairing a crack in stressed skin.

The rivet pattern is laid out on the patch, using the proper edge distance and spacing. The installation position of each rivet is marked with a center punch. The impression in the material made with the center punch helps to keep the



AM.344

Figure 7-4.—Drilling holes for rivets.

drill from slipping away from the hole being drilled. (See fig. 7-4). Drill only a minimum number of rivet holes in the patch, normally four will suffice at an angle of 90 degrees to each other. Position the patch over the surface being repaired, insuring that the correct edge distances are being maintained. Drill four holes in the surface being repaired, using the predrilled holes in the patch as a pattern for alignment. As each hole is drilled, using the proper temporary fasteners, secure the patch in place. When the patch is temporarily secured, drill the remaining rivet holes through the patch and surface being repaired. Remove the patch and deburr all rivet holes, using a deburring tool or a large drill bit. Prime the repair materials with the proper corrosion preventive material prior to the riveting operation. Secure the patch in position, using temporary fasteners, to maintain alignment during riveting. Riveting procedures are covered later in this chapter.

Holes may be repaired in either stressed or nonstressed skin which are less than 3/16 inch in diameter by filling with a rivet. Drill the hole and install the proper size rivet to fill the hole. For holes 3/16 inch and larger, the AMS should consult the applicable Structural Repair Manual for the necessary repair information. The damaged area is removed by cutting and trimming the hole to a circular, square, rectangular, or diamond shape. The corners of the hole should be rounded to a minimum of 1/4-inch radius. The lap patch is fabricated and installed in the same manner as previously explained for repairing cracks.

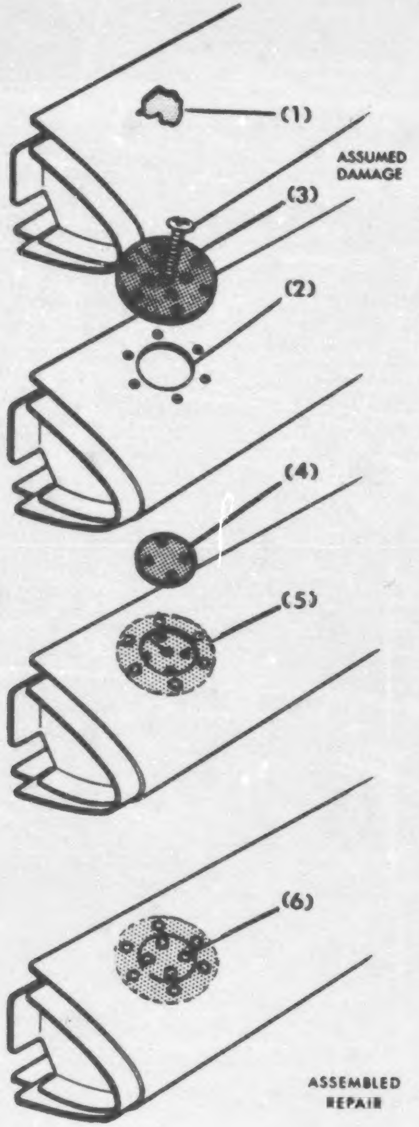
Flush Patches

Flush patches should be used where aerodynamic smoothness is required. The type of flush patch used depends on the location of the damaged area. One type is clear of internal structures, and the other it is not. Like all types of repairs, the AMS must consult the applicable Structural Repair Manual for the necessary repair information. The repairs discussed next are typical of most repairs.

FLUSH PATCH CLEAR OF INTERNAL STRUCTURES.–In areas which are clear of internal structure, the repair is relatively simple to make. This is especially true where there is an access door or plate through which the rivets can be bucked. In inaccessible areas, the flush patch may be made by substituting blind rivets for standard rivets, where permissible, and devising a means of inserting the doubler through the opening.

One method is shown in figure 7-5, in which the doubler has been split. To insert the doubler, slip the split edge under the skin and twist the doubler until it slides in place under the skin. The screw in the center of the doubler is temporarily installed to serve as a "handle" for inserting the doubler through the hole. This type of patch is normally recommended for holes up to 1 1/2 inches in diameter. It is generally more satisfactory to trim a hole larger than 1 1/2 inches to a rectangular or elliptical shape, rounding all corners to a generous radius. (See fig. 7-6.)

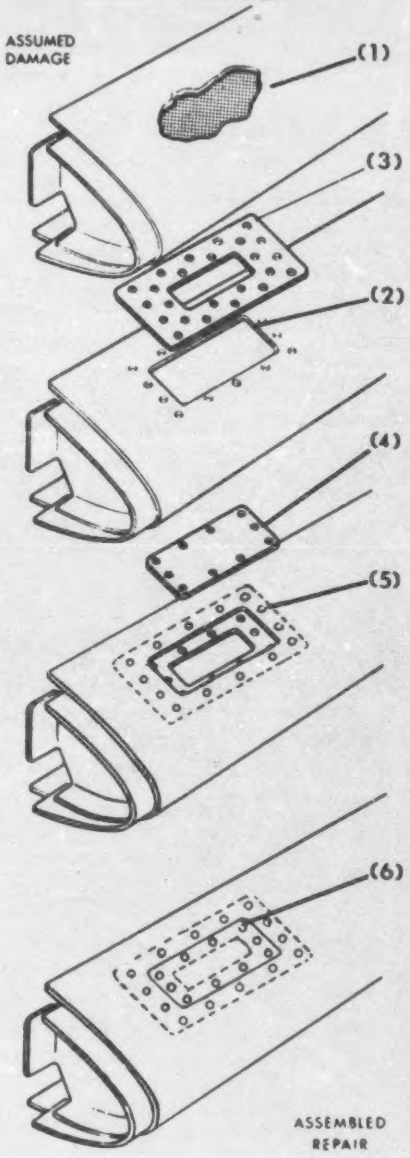
On larger repair areas it is usually possible to buck the doubler rivets by inserting and holding the bucking bar through the center of the doubler. The filler is then riveted in place using blind fasteners, if in a closed skin area. When blind rivets are used as substitutes for solid rivets, the Structural Repair Manual normally specifies the next larger size. The proper edge



AM.345

(1) Assumed damage. (2) Damage cut out to a smooth round hole. (3) Doubler split for insertion through cut out. (4) Filler. (5) Doubler riveted in place. (6) Filler riveted in place.

Figure 7-5.—Repair of small holes in skin with a flush patch.



AM.346

(1) Assumed damage. (2) Damage cut out to smooth rectangular shape. (3) Doubler. (4) Filler. (5) Doubler riveted in place. (6) Filler riveted in place.

Figure 7-6.—Flush rectangular patch.

distances for the substitute fasteners must be maintained.

NOTE: Edge distance is discussed later. In all flush patches, the filler should be of the same gage and material as the original skin. The doubler, generally, should be of the same material, one gage heavier than the skin. Structural Repair Manuals will specify the allowable substitution of materials. This can be in the form of a note on the repair diagram. For example, the RA-3B Structural Repair Manual shows the following information in the form of a note:

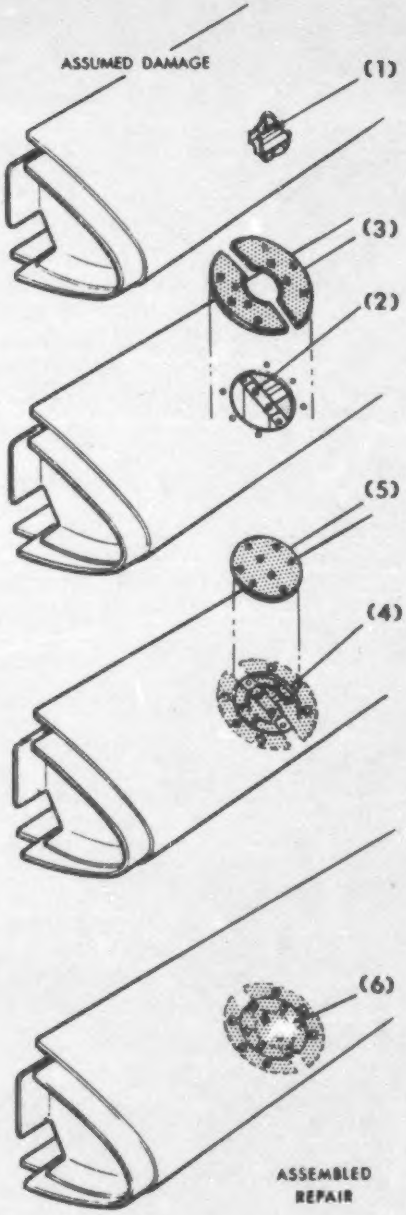
> Curved sheet: When substituting 2024-T for 0.025 to 0.071 inch 7075-T, the 2024-T should be one gage heavier than called for in 7075-T; if the gage of the 7075-T is 0.080 or 0.090 inch the 2024-T should be two gages heavier than the 7075-T.
>
> Flat sheet: Substitute one gage heavier 2024-T for all 7075-T skin gages.

When laying out the size of the doubler, the length should exceed the width. This enables the doubler to be slipped in through the skin, so it can be positioned for installation. This eliminates the splitting and manipulation of the patch required in installing doublers of square and round flush patch repairs.

The filler is fabricated slightly less than the dimensions of the hole being repaired. Generally, the maximum clearance between the skin and the filler is 1/32 inch. The doubler is fabricated larger than the hole being repaired to allow for the specified number of rivets required to attach the doubler to the skin being repaired. The doubler, filler, and attaching skin rivet pattern may be laid out, drilled, and deburred in the identical manner as described previously for a lap patch. After the required corrosion preventive materials have been applied, the doubler is positioned in the structures interior and secured with temporary fasteners. Inspect the rivet holes for proper alignment and rivet the doubler in place, using solid rivets. The filler can then be riveted in place using blind fasteners.

NOTE: If the flush repair is in an open skin area, the filler may be riveted to the doubler prior to installing the doubler.

FLUSH PATCH OVER INTERNAL STRUCTURES.—Fabricating a flush patch over



AM.347

(1) Assumed damage. (2) Damaged skin cut out to a smooth round hole and rib repaired. (3) Two half-round doublers. (4) Doublers riveted in place. (5) Filler. (6) Filler riveted in place.

Figure 7-7.—Flush patch over internal structure.

internal structure may tend to become difficult. In some instances, it may be done by simply using a split doubler and a filler, as shown in figure 7-7. Frequently a split doubler, filler strips, and filler are used in the repair. The filler strip is used as a spacer, if a structural component under the skin has been damaged. In all cases, the existing structure rivet holes should be used when the rivet pattern is laid out. The flush patch over internal structure is installed using the same methods as described for a flush patch clear of internal structure, except for modification of the doubler.

Flush Access Door

A flush access door installation, as shown in figure 7-8, is sometimes permitted. It is installed to facilitate repair to the internal structure and to repair damage to the skin in certain areas. The flush access door consists of a doubler and a stressed cover plate. The cover plate is normally fabricated from material identical to the skin. A single row of nut plates is riveted to the doubler, and the doubler is then riveted to the interior side of the skin with two rows of rivets, staggered as shown in figure 7-8. The cover plate is attached to the doubler with machine screws. When an access door is permitted and installed over internal structure, screws should be installed through the cover plate into the internal structural member wherever possible.

Skin Replacement

Sometimes damage to the metal skin is so extensive that an entire panel must be replaced. Also, an excessive number of patches or minor repairs to a section or area may require the replacement of the entire panel.

As in all other forms of repairs, the first step is to inspect the damaged area thoroughly to

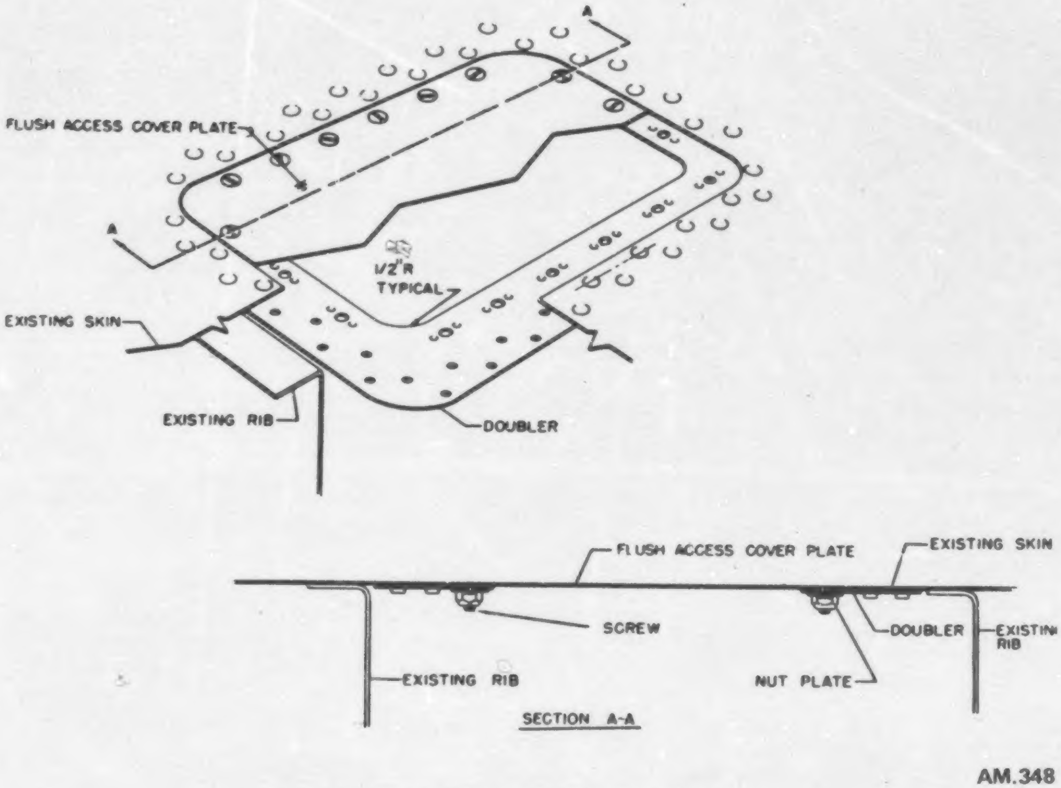


Figure 7-8.–Flush access door installation.

determine the extent of the damage. Inspect the internal structure for damage or signs of strain. Such members, when bent, fractured, or wrinkled, must be replaced or repaired. They may be sheared considerably without visible external evidence of such a condition. Drill out rivets at various points in the damaged area and examine them for signs of shear failure.

During the inspection, note carefully all unusual riveting problems–conditions which render riveting difficult or which make replacement impossible. Any fixtures which will hinder riveting and prevent the use of straight bucking bars will be apparent in a thorough inspection. There will also be places where flanges or reinforcing members, or the intersection of stringers, longerons, formers, frames, or rings make the bucking of rivets very difficult. This problem can be solved by designing and making bucking bars to suit these particular situations.

Care must be taken to avoid mutilating the damaged skin in the process of removal. In most cases it can be used as a template for layout of and drilling holes in the new piece of skin.

The rivet holes in stringers, longerons, bulkheads, formers, frames, rings, and other internal members must be kept in as good condition as possible. If any of these members are loosened by the removal of rivets, their location should be marked so that they can be returned to their original position as necessary, while the repair is being made.

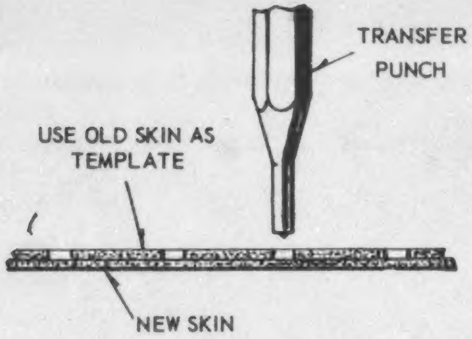
Reference should be made to the applicable repair material chart in the aircraft Structural Repair Manual for the gage and alloy of material to be used for the replacement panel. The size and shape of the panel may be determined in either of two ways. The dimensions can be measured during the inspection, or the old skin can be used as a template for the layout of the sheet and the location of the holes, the latter method being preferable and more accurate. Regardless of the procedure used, the new sheet must be large enough to replace the damaged area, and may be cut with an allowance of 1 to 2 inches of material outside the rivet holes.

If the old sheet is not too badly damaged, it should be flattened out and used as a template. The new sheet, having been cut approximately 1 inch larger than the old, should then be drilled near the center of the sheet, using the holes in the old sheet as a guide. The two sheets are then fastened together with sheet metal fasteners. The use of sheet metal screws is not recommended since they injure the edges of the rivet holes. The drilling should proceed from the center to the outside of the sheet, inserting sheet metal fasteners at frequent intervals.

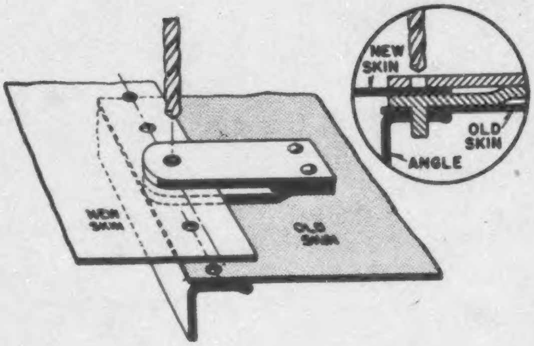
If impossible to use the old sheet as a template, the holes in the new sheet should be drilled from the inside of the structure. Use the holes in the reinforcing members as guides, and insert fasteners in the same manner as described above. This is called back-drilling. Before placing the new sheet on the framework to drill the holes, make certain that the reinforcing members are aligned and flush at the points at which they intersect, otherwise the holes in the new sheets will not be accurately aligned. For the same reason, the new sheet should have the same contour as the old before drilling the rivet holes.

In duplicating holes from reinforcing members to skin, extreme care must be exercised or both frame and skin will be ruined. Since most bulkheads, ribs, and stringers depend on the skin for some of their rigidity, they can easily be forced out of alignment in the drilling process. The skin must be held firmly against the framework, or the pressure from the drilling will force it away from the frame and cause the holes to be out of alignment. This may be overcome by placing a block of wood against the skin and holding if firmly while the drilling progresses. Also, make sure that the drill is held at a 90-degree angle to the skin at all times, or the holes will be elongated and out of alignment. When drilling through anchor nuts a smaller pilot drill should be used first. Care must be used so as not to damage the anchor nut threads. The pilot holes are then enlarged to the proper size.

It may be necessary to use an angle attachment or flexible shaft drill in places where it is impossible to insert a straight drill. In case neither type can be inserted, the new section can be marked carefully with a soft pencil through the holes in the old section. Another method of marking the location of the new holes is to use a transfer or prick punch as shown in figure 7-9. Center the punch in the old hole, then tap the punch lightly with a hammer. The result should



AM.349
Figure 7-9.—Transferring rivet holes.



AM.350
Figure 7-10.—Using a hole finder.

be a mark which will serve to locate the hole in the new sheet.

Still another way to locate the rivet holes without a template is to use a hole finder, similar to the one shown in figure 7-10. This device makes it possible to drill holes in the new section of skin in perfect alignment with the holes in the old section. The hole finder is made in two sections—an upper part and a lower part which are fastened together at one end.

At the free end of the botton section of the hole finder is a guide rivet which drops into the old holes in the sheet still in place. The free end of the top section of the hole finder has a hole in a position which exactly matches the position of the guide rivet, and through this opening the new hole is drilled. Thus, as the hole finder is moved along, the guide rivet drops into an old hole and automatically determines the position of the new hole.

After all the holes have been drilled, the temporary fasteners are taken out and the sheet is removed from the framework. The burrs left by drilling must be removed from both sides of all holes in the skin, the stringers, and the rib flanges. Burring may be accomplished with a few light turns of a deburring tool or drill bit. In this way particles of metal left around the edges of the drilled holes are eliminated. If they were not removed, the joint would not be tight and rivets might expand, or flash, between the parts being riveted.

REINFORCED PLASTIC AND SANDWICH CONSTRUCTION REPAIR

This section deals with the materials and procedures to be used in repairing reinforced plastic and sandwich construction components. The procedures discussed are general in nature. When actually repairing reinforced plastic and/or sandwich construction components, refer to the applicable Structural Repair Manual.

REPAIR OF REINFORCED PLASTIC

The repair of any damaged component made of reinforced plastic requires the use of identical materials, whenever they are available, or of approved substitutes for rebuilding the damaged portion. Abrupt changes in cross-sectional areas must be avoided by tapering joints, by making small patches round or oval instead of rectangular, and by rounding the corners of all large repairs. Uniformity of thickness of core and facings is exceedingly important in the repair of radomes. Repairs of punctured facings and fractured cores, therefore, necessitate removal of all the damaged material, followed by replacement with the same type of material and in the same thickness as the original.

All repairs to components housing radar or radio gear must be made in accordance with the manufacturer's recommendations. This information may be found in the aircraft Structural Repair Manual or in drawings and specifications.

Investigation of Damage

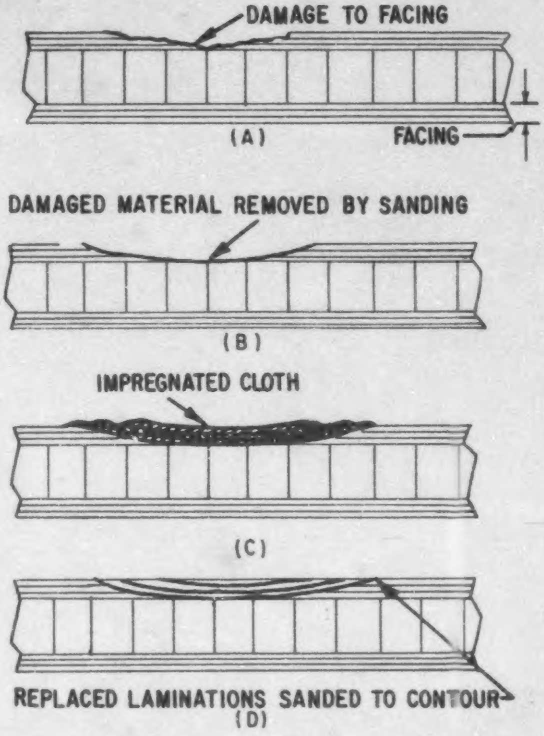
Before a thorough inspection of the damage can be made, the area should be cleaned with a cloth saturated with methyl-ethyl-ketone (MEK). After drying, the paint should be removed by sanding lightly with No. 280 grit sandpaper, then clean the sanded area with MEK. The extent of damage can then be determined by tapping the suspected areas with a blunt instrument. The damaged areas will have a dull or dead sound, while the undamaged areas will have a clear metallic sound.

Damages are divided into four general classes: surface damage, facing and core damage, puncture damage (both facings and core), and damage requiring replacement.

Surface Damage

The most common types of damage to the surface are abrasions, scratches, scars, dents, cuts, and pits. Minor surface damages may be repaired by applying one or more coats of room-temperature catalyzed resin to the damaged area. More severe damages may be repaired by filling with a paste made from room-temperature resin and short glass fibers. Over this coated surface, apply a sheet of cellophane, extending 2 or 3 inches beyond the repaired area. After the cellophane is taped in place, work out all the air bubbles and excessive resin with the hand or a rubber squeegee. Allow the resin to cure at room temperature, or if necessary, the cure can be hastened by the use of infrared lamps or hot sandbags. After the resin has been cured, remove the cellophane and sand off the excess resin; then the entire repaired area is lightly sanded preparatory to refinishing.

PLY DAMAGE (SANDWICH TYPE LAMINATES).–When the damage has penetrated more than one ply of the cloth in the sandwich type laminates, the repair may be made using the scarfed method illustrated in figure 7-11. This repair is made in the following manner: Sand out the damaged laminate plies as shown in view (B). The area should be sanded to a circular or oval shape, then the area should be tapered uniformly down to the deepest penetration of the damage.


DAMAGE TO FACING
(A)
FACING
DAMAGED MATERIAL REMOVED BY SANDING
(B)
IMPREGNATED CLOTH
(C)
REPLACED LAMINATIONS SANDED TO CONTOUR
(D)

AM.351

Figure 7-11.—Ply repair (scarfed method).

The diameter of the scarfed (tapered) area should be at least 100 times the depth of the penetration. Care should be exercised when using a mechanical sander. Excess pressure on the sander can cause the sandpaper to grab, resulting in the delamination of undamaged plies.

CAUTION: The sanding of glass cloth reinforced laminates produces a fine dust that may cause skin irritation. In addition, breathing of an excessive amount of this dust may be injurious;

therefore, precautions as to skin and respiration protection must be observed.

Brush coat the sanded area with one coat of room-temperature-setting resin and apply the contoured pieces of resin-impregnated cloth, as shown in (C) of figure 7-11. Tape a sheet of cellophane over the built-up repair and work out the excess resin and air bubbles. Cure the repair in accordance with the resin manufacturer's instructions, then sand the surface down (if necessary) to the original surface of the facing.

PLY DAMAGE (SOLID LAMINATES).–Ply damage to solid laminates may be repaired using the scarfed method described for sandwich type laminates, or the stepped method shown in figure 7-12 (A) may be used.

When the wall is being prepared for the stepped repair, a cutting tool with a controlled depth will facilitate the cutout and should be used to avoid possible damage to the layers underneath. If the layer of glass cloth underneath is scratched or cut, the strength of the repair will be lessened. Care should be exercised not to peel back or rupture the adhesion of the laminate layers beyond the cutout perimeter. Removal of the cutouts may be accomplished by peeling from the center and working carefully to the desired perimeter of the cutout. Scrape each step, wipe clean with cloths moistened with MEK, and allow to dry thoroughly. Cut the replacement glass fabric pieces to an exact fit with the weave directions of the replacement plies running in the same direction as the existing plies. Failure to maintain the existing weave direction will result in a repair that is greatly under strength. Replace each piece of fabric, being careful to butt the existing layers of fabric plies together, but do not overlap them. The laminate layers should be kept to the proper matching thickness.

When the entire wall has been penetrated, as shown in figure 7-12 (B), one-half of the damaged plies should be removed from one side and the replacement buildup completed, then repeat removal and buildup procedure on the opposite side. If the damage occurs over a relatively large or curved area, make up a plaster mold conforming to the contour and extending 1 inch past the damage, and insert it in the damaged area when repairing the first half of the plies. When the stepped method of repair is used, the dimensions should be maintained as illustrated.

In areas that have become delaminated, or contain voids or bubbles, clean the area with MEK and determine the extent of the delamination, then drill holes at each end or on the opposite sides of the void using a No. 55 drill bit, extending through the delaminated plies. Figure 7-13 illustrates the procedure for repair of delaminated plies.

Additional holes may be needed if air entrapment occurs when injecting the resin. Using a hypodermic needle or syringe, slowly inject the appropriate amount of resin until the void is filled and flows freely from the drilled holes. After the voids are completely filled, bring the area down to proper thickness by working the excess resin out through the holes, then cure and refinish.

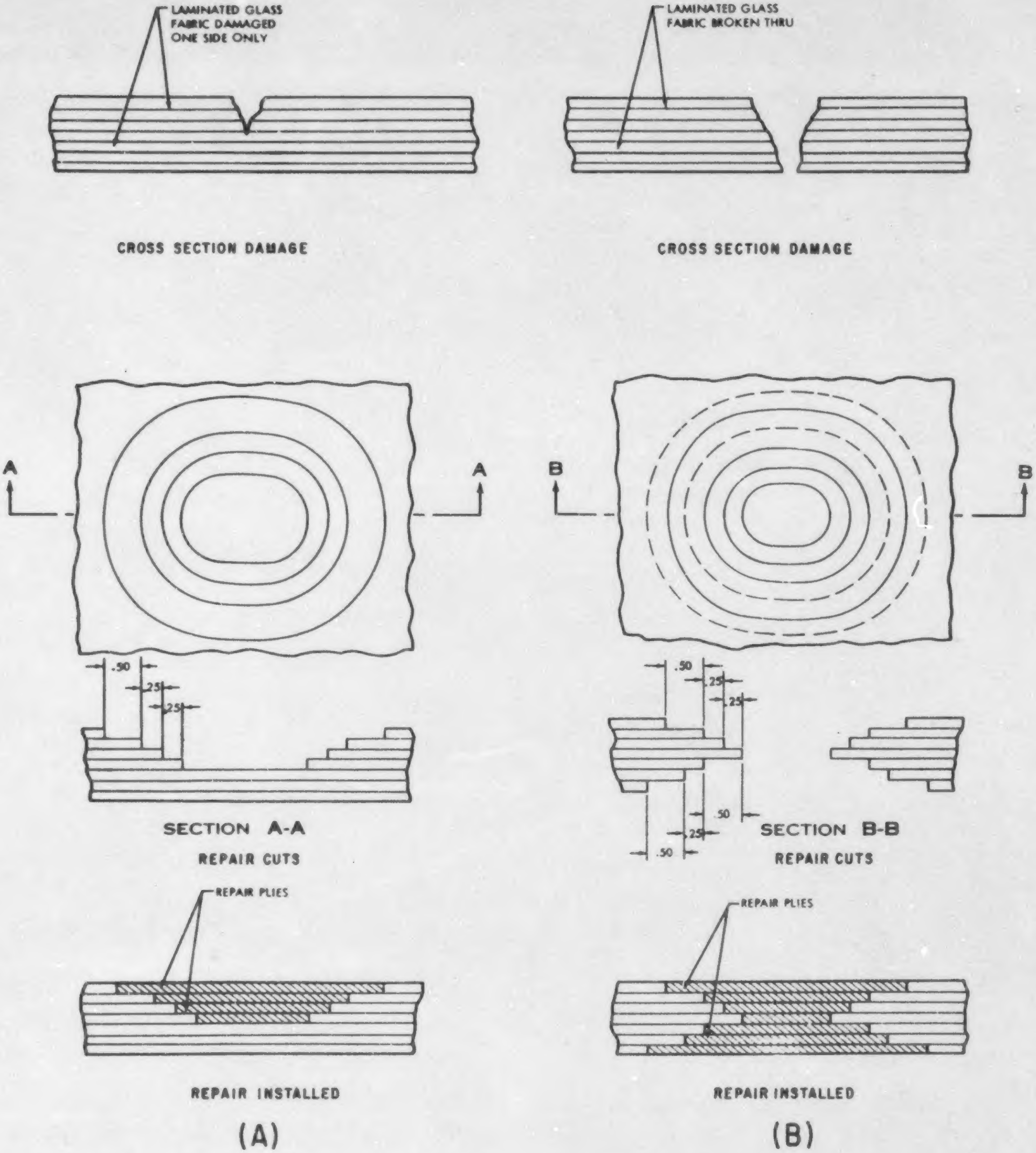
Facing and Core Damage

HONEYCOMB CORE.–Damages extending completely through one facing of the material and into the core require removal of the damaged core and replacement of the damaged facings in such a manner that normal stresses can be carried over the area. The scarfed method illustrated in figure 7-14 is the preferred method for accomplishing small repairs of this type. Repairs of this type may be accomplished as follows:

Carefully trim out the damaged portion to a circular or oval shape and remove the core completely to the opposite facing. Be careful not to damage the opposite facing. The damaged facing around the trimmed hole is then scarfed back carefully by sanding. The length of the scarf should be at least 100 times the facing thickness as shown in (B) of figure 7-14. This scarfing operation must be done vary accurately to a uniform taper.

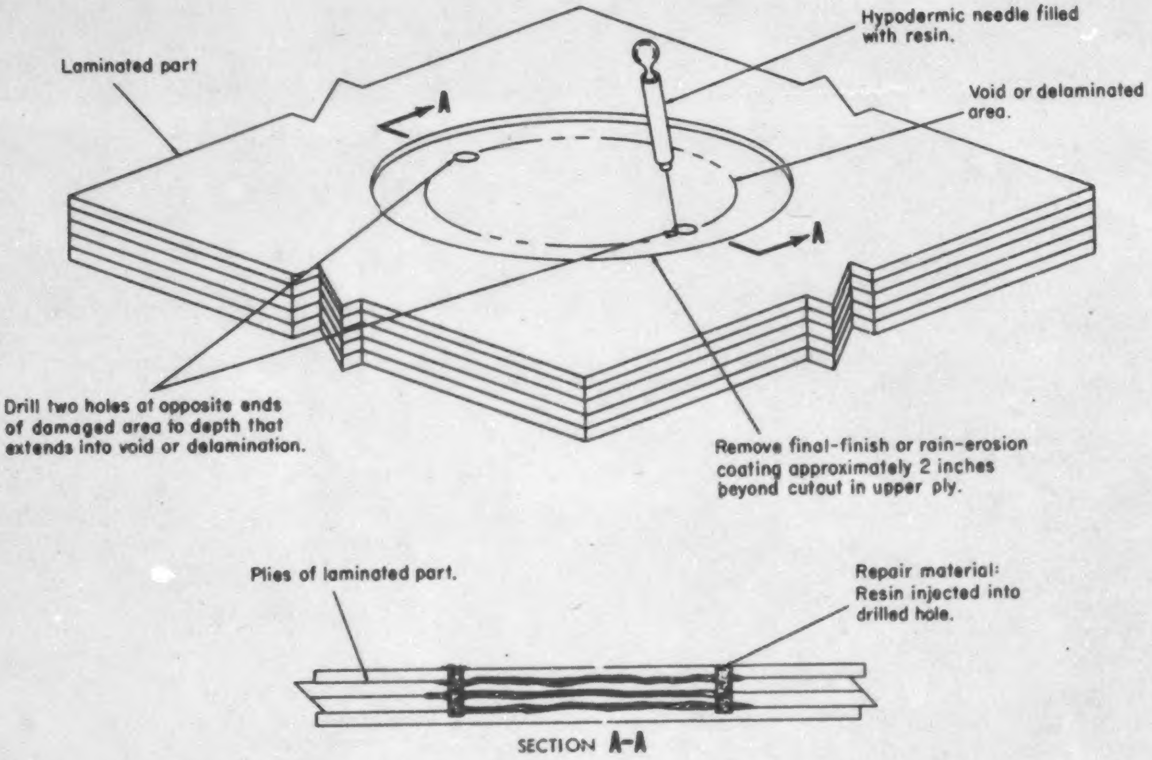
Cut a piece of replacement core material (or a suitable substitute) to fit snugly in the trimmed hole. It should be equal in thickness to the original core material. Brush coat the repair area and the replacement honeycomb, exercising care to prevent an excessive amount of resin from entering the honeycomb cells.

Insert the honeycomb repair section and place the resin-impregnated cloth over the repair area



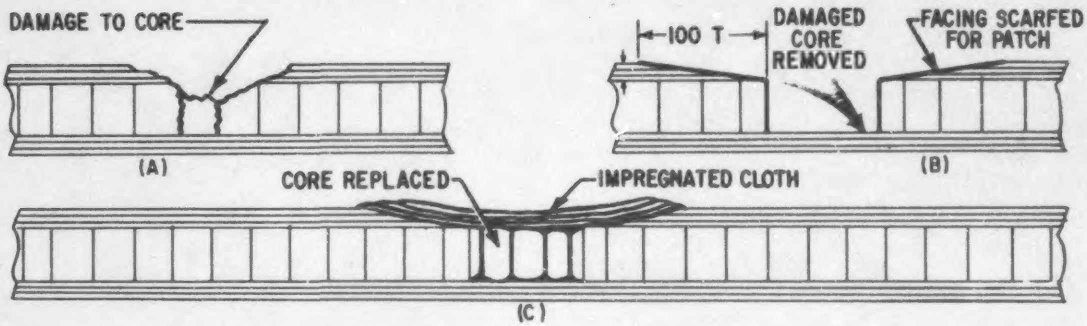
AM.352

Figure 7-12.—Repair of solid laminates (stepped method).


Laminated part
Hypodermic needle filled with resin.
A
Void or delaminated area.
A
Drill two holes at opposite ends of damaged area to depth that extends into void or delamination.
Remove final-finish or rain-erosion coating approximately 2 inches beyond cutout in upper ply.
Plies of laminated part.
Repair material: Resin injected into drilled hole.
SECTION A-A

AM.353

Figure 7-13.–Delaminated ply repair.



AM.354

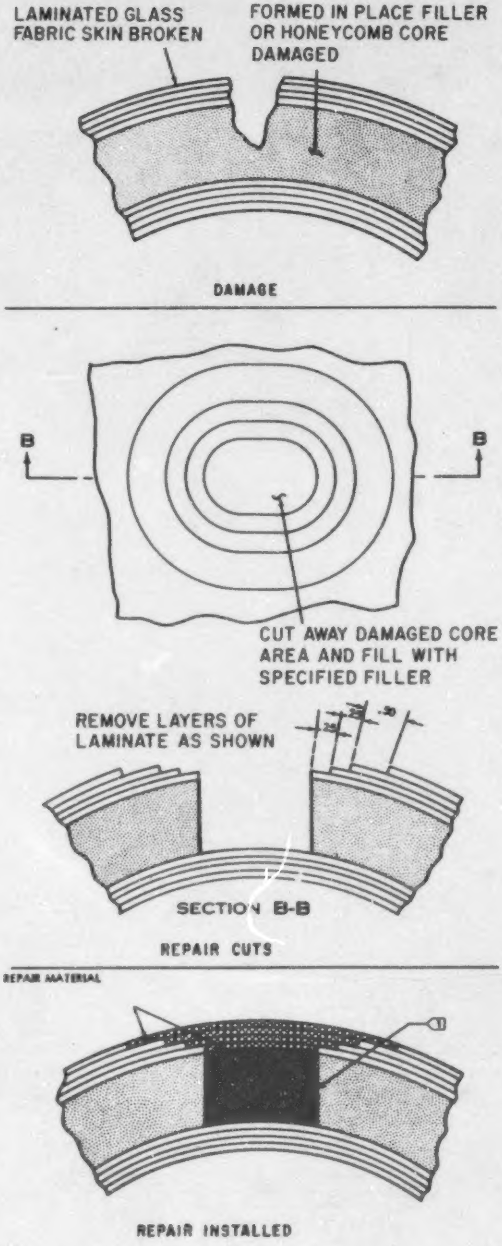
Figure 7-14.–Honeycomb type core repair.

as shown in (C) of figure 7-14. Cover the repair area with cellophane sheeting and cure the repair in accordance with the resin manufacturer's instructions.

After the repair has been cured, sand the surface to its original contour. The entire area should be lightly sanded before refinishing.

FOAM TYPE CORE.–The damaged core should be removed by cutting perpendicular to the surface of the face laminate opposite the damaged face. Scrape the inner facing surface clean, making sure there is no oil or grease film in the area, to insure good bondage of the foam to the laminate. Fill the area where the core has been removed with the filler material specified in the aircraft Structural Repair Manual. Figure 7-15 illustrates the replacement of a foam type core.

NOTE: Do not use MEK to clean the damage as it may soften and weaken the foam.


LAMINATED GLASS FABRIC SKIN BROKEN
FORMED IN PLACE FILLER OR HONEYCOMB CORE DAMAGED
DAMAGE
B
B
CUT AWAY DAMAGED CORE AREA AND FILL WITH SPECIFIED FILLER
REMOVE LAYERS OF LAMINATE AS SHOWN
.25
.25
.30
SECTION B-B
REPAIR CUTS
REPAIR MATERIAL
1
REPAIR INSTALLED

NOTE

1 REPLACE DAMAGED CORE MATERIAL WITH SPECIFIED FILLER

AM.355

Figure 7-15.–Foam type core repair.

Puncture Damage

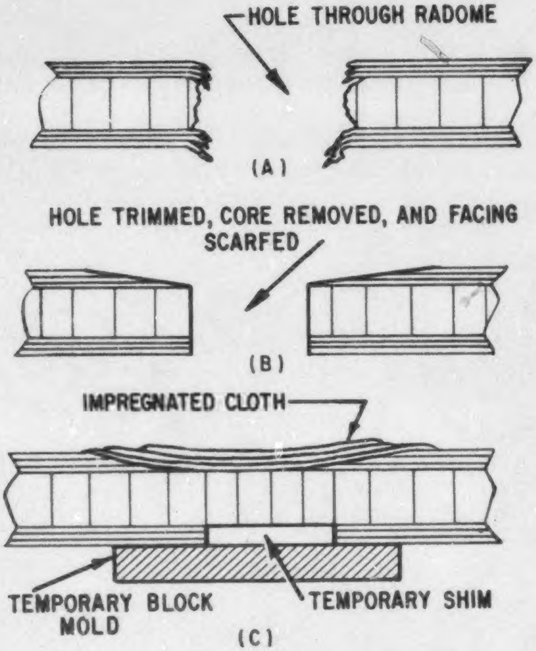
HONEYCOMB CORE.–Repairs to damages completely through the sandwich structure may be accomplished either by the scarfed method (similar to the repair described for damage extending into the core) or the stepped method.

The scarfed method is normally used on small punctures up to 3 or 4 inches in maximum dimension and in facings made of thin cloths (which are difficult to peel), whereas the stepped method is usually employed on larger repairs to facings composed of thick cloths.

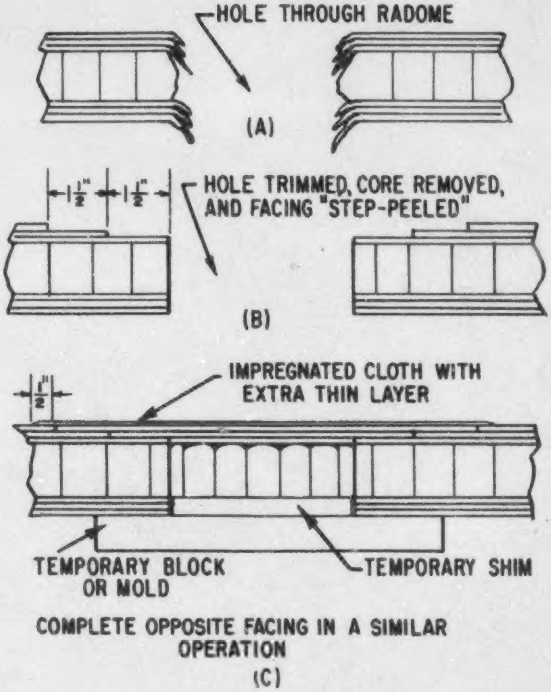
The scarfed method of repair for punctures is the same as that used for damage extending into the core, with the exception that the opposite side of the sandwich is provided with a temporary mold or block to hold the core in place during the first step. (See (C) fig. 7-16.)

After the first facing repair is cured completely, the mold and the shim (temporarily replacing the facing on the opposite side) are removed. The repair is then completed by repeating the procedure used in the first step. When this facing is cured, the surface should be sanded down to the original contour and the repair area lightly sanded in preparation for refinishing.

When using the stepped method of repair, the damaged area is first trimmed out to a round or



AM.356
Figure 7-16.–Scarfed repair method.


HOLE THROUGH RADOME
(A)
1½"
1½"
HOLE TRIMMED, CORE REMOVED, AND FACING "STEP-PEELED"
(B)
½"
IMPREGNATED CLOTH WITH EXTRA THIN LAYER
TEMPORARY BLOCK OR MOLD
TEMPORARY SHIM
COMPLETE OPPOSITE FACING IN A SIMILAR OPERATION
(C)

AM.357
Figure 7-17.–Stepped repair method.

oval shape, or to a rectangular or square shape (preferable having rounded corners).

The individual plies are then cut out as illustrated in figure 7-17. Each ply is "stepped" back 1-1/2 inches and trimmed out using a sharp knife. The sides of the repair should be parallel with the weave of the cloth, if possible.

NOTE: Do not cut through more than one layer of cloth. If the layer of cloth underneath is scratched, the strength of the repair will suffer.

The opposite facing is shimmed and backed up with a mold and the core material is inserted as previously described. The outer repair plies are soaked in the resin and laid over the damaged area. An extra layer of thin cloth is laid over the repair area to extend one-half inch over the undamaged facing. The repair area is then covered with a sheet of cellophane to apply pressure, and allowed to cure.

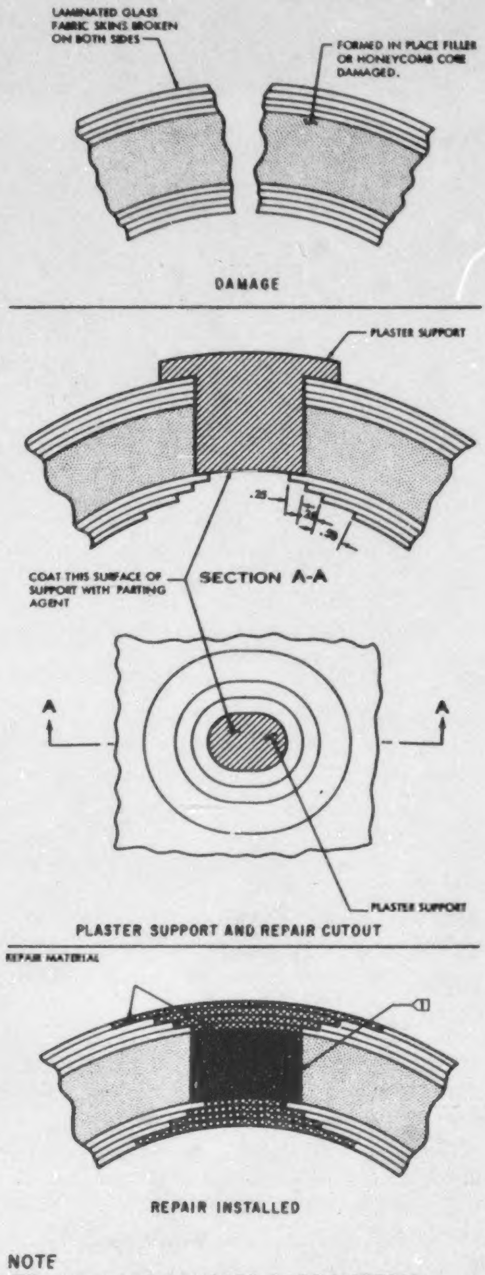
The inner facing is then replaced in the same manner as the outer facing. After the inner repair has been cured, the entire repair area should be sanded to the original contour and prepared for refinishing.

FOAM TYPE CORE.–When the puncture penetrates the entire wall, remove the damaged core and face laminates to one-fourth inch past the perimeter of the hole on the inner face. Make a plaster support to replace the removed core, conforming to the curvature of the inside layer of the inner face. Figure 7-18 illustrates a punctured repair with a plaster support.

After repair to the inner face has been completed, remove the plaster support and continue the repair on the opposite side.

Finishing of Repaired Areas

In the repair of reinforced plastic parts, the


LAMINATED GLASS FABRIC SKINS BROKEN ON BOTH SIDES
FORMED IN PLACE FILLER OR HONEYCOMB CORE DAMAGED.
DAMAGE
PLASTER SUPPORT
.25
.25
COAT THIS SURFACE OF SUPPORT WITH PARTING AGENT
SECTION A-A
A
A
PLASTER SUPPORT
PLASTER SUPPORT AND REPAIR CUTOUT
REPAIR MATERIAL
1
REPAIR INSTALLED

NOTE
1 REPLACE DAMAGED CORE MATERIAL WITH SPECIFIED FILLER

AM.358
Figure 7-18.—Foam type puncture repair.

final step is to refinish the part with a finish identical to the original, or an acceptable substitute. In refinishing radomes and other surfaces which enclose electronic equipment, do not use metallic pigmented paints or other electronic reflective type materials because of undesirable shielding and interference effects. Always use the materials recommended in the applicable Structural Repair Manual for refinishing both the interior and exterior surfaces of reinforced plastic components.

Reinforced plastic components whose frontal areas are exposed to high speeds are frequently coated with a rain erosion coating. Rain erosion coatings protect the component against pits which are caused by raindrops hitting the component at high aircraft speeds. These pits or eroded areas can cause delamination of the component glass cloths if allowed to progress unchecked.

RAIN EROSION RESISTANT COATINGS.—Rain erosion resistant coatings for reinforced plastic components conform to Specification MIL-C-7439. Coatings conforming to this specification are classified as follows:

Class I is a rain erosion resistant coating which is furnished in kit form. This kit consists of a primer, accelerator, diluting solvent, and neoprene.

Class II is a rain erosion resistant coating with an additional surface treatment to minimize radio noise resulting from precipitation static on the coated surface. This coating is also supplied in kit form and consists of a primer, accelerator, diluting solvent, neoprene, and antistatic coating.

These kits (MIL-C-7439, Classes I and II) are packaged unaccelerated to provide longer shelf life. The neoprene is ready to use only after the catalyst (accelerator) has been added. The material in these kits should be mixed and applied in accordance with the instruction sheet supplied by the kit manufacturer.

Safety Precautions

The following general safety precautions should be observed when making repairs to reinforced plastic components. These safety precautions should be reviewed before attempting any repairs to reinforced plastics.

1. Local station safety regulations as to fire and health hazards must be complied with.
2. All solvents are flammable, therefore, observe proper handling procedures.
3. Personnel involved in the mixing or handling of catalyzed resin prior to the curing operation should wear rubber gloves. After using rubber gloves, the hands should be cleaned with soap and water and rinsed with vinegar to neutralize any catalyst particles.
4. Never mix the catalyst and promoter together as they are explosively reactive as a mixture. Always mix the promoter with the resin first and then add the catalyst to the mixture.
5. The toxicity of polyester formulation has not been definitely established. Some of the components are known to cause nasal or skin irritation to certain individuals. Adequate ventilation should be provided.
6. The sanding operation on glass cloth reinforced laminates gives off a fine dust that may cause skin or respiratory irritations. Inhalation of excessive amounts of this dust should be avoided. Protection should be provided for respiration and skin.
7. Do not store catalyzed resin in an air-tight container or an unvented refrigerator.

REPAIR OF SANDWICH CONSTRUCTION (HONEYCOMB AND BALSA WOOD CORE)

The repairs discussed in this section are applicable to structural type sandwich construction consisting of aluminum alloy facings bonded to aluminum honeycomb and balsa wood cores.

Minor Surface Damage

The most common types of damage to the surface are abrasions, scratches, scars, and minor dents. These minor surface damages require no repair other than the replacement of the original protective coating to prevent corrosion; provided no breaks, holes, or cracks exist. The procedures and materials used in replacing the original protective coating are outlined in chapter 11.

Delamination

Facing-to-core voids of less than 2.5 inches in diameter can usually be repaired by drilling a series of holes 0.06 to 0.10 inch in diameter in the upper facing over the void area. An expandable foaming resin, such as Thermofoam 607, or equivalent, is then injected through the holes with a pressure type caulking gun.

When the void is on the lower surface of the panel, only sufficient resin must be injected as to completely fill the void. With voids on the upper surface, the core area should be filled until the resin comes out of the injection holes. These holes should be sealed with a thermosetting epoxy resin adhesive, and the entire assembly cured with lamps, as required for the adhesive system.

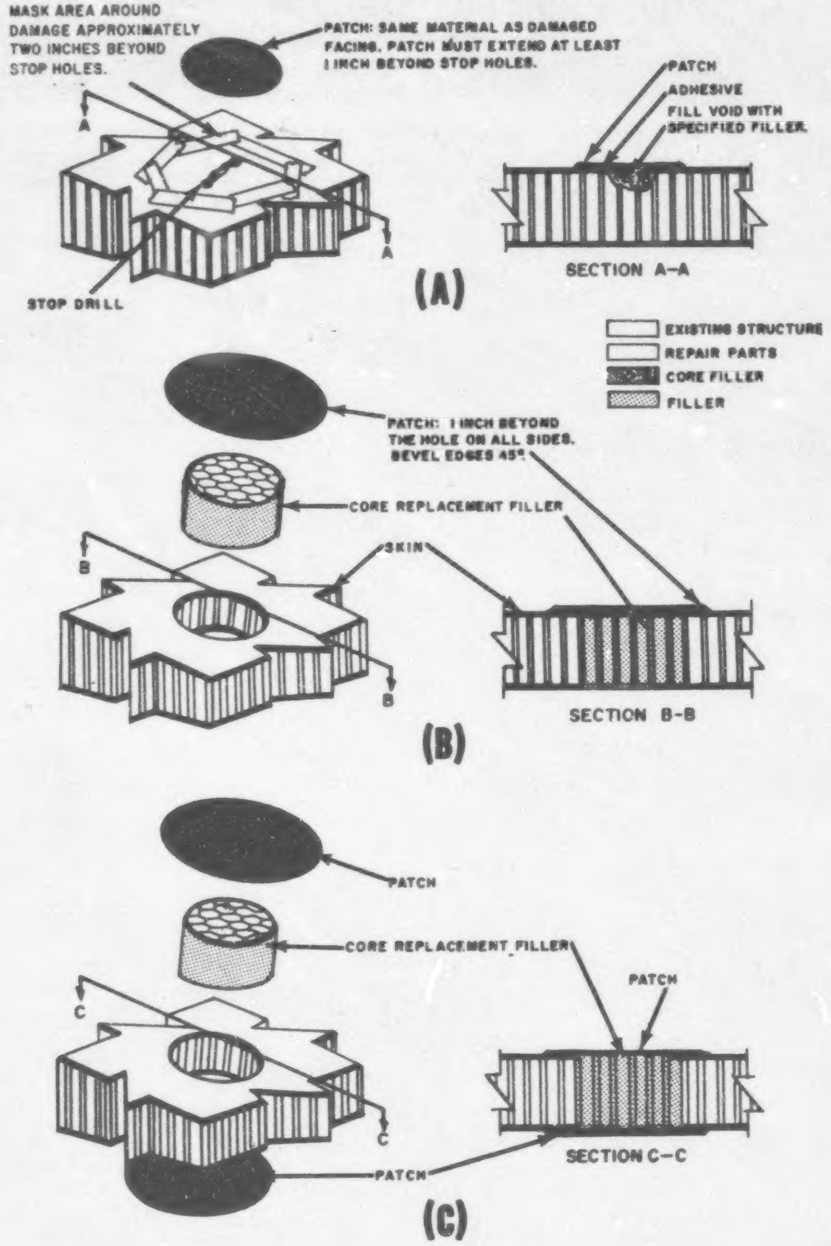
When the void areas are large, it is necessary to remove the facing over the damaged area and follow the repair procedures for a puncture. (See fig. 7-19.)

Punctures

A puncture is defined as a crack, break, or hole through one or both skin facings with resulting damage to the honeycomb and/or balsa wood core. The size of the puncture, amount of damage to the core, assembly to be repaired (rubber, elevator, etc.), and previous repairs to the damaged assembly are factors to be considered in determining the type of repair to be made. Damage to a honeycomb and/or balsa wood core assembly that exceeds a specified length or diameter in inches or the total number of repairs exceeds a specified percentage of the total bonded area necessitates replacement of the assembly.

NOTE: These figures are found in the applicable Structural Repair Manual.

HONEYCOMB CORE.–The repair shown in figure 7-19 (A) is used when a puncture through one skin facing has caused only minor damage to the core material. To repair this type damage proceed as follows: Cover the component with a suitable protective covering (polyvinyl sheet or kraft paper). Cut out a section of the protective covering that will extend approximately 2 inches beyond the damaged area. Use masking tape to


MASK AREA AROUND DAMAGE APPROXIMATELY TWO INCHES BEYOND STOP HOLES.
PATCH: SAME MATERIAL AS DAMAGED FACING. PATCH MUST EXTEND AT LEAST 1 INCH BEYOND STOP HOLES.
A
A
STOP DRILL
PATCH
ADHESIVE
FILL VOID WITH SPECIFIED FILLER.
SECTION A–A
(A)
EXISTING STRUCTURE
REPAIR PARTS
CORE FILLER
FILLER
PATCH: 1 INCH BEYOND THE HOLE ON ALL SIDES. BEVEL EDGES 45°
CORE REPLACEMENT FILLER
SKIN
B
B
SECTION B–B
(B)
PATCH
CORE REPLACEMENT FILLER
PATCH
C
C
SECTION C–C
PATCH
(C)

AM.359

(A) Skin facing, minor damage to core;
(B) Skin facing, extensive damage to core;
(C) Skin facings and core damaged.

Figure 7-19.—Sandwich construction puncture repair (honeycomb core).

hold the cutout in place. Stop-drill as necessary through the skin facing only.

Strip the paint and protective coating 1 1/2 inches beyond the stop-drilled holes. The stripped area is then cleaned with a special cleaning paste. Fill the void with the specified filler material to within approximately 0.063 inch of the skin facing and cure as directed.

Prepare a round or oval patch large enough to overlap the damaged area at least 1 inch. Apply sealant to the undersurface of the patch and to the filler and skin surface. Install the repair patch, maintaining correct overlap, and clamp to the assembly to assure contact with the skin facing. Cure as directed. Remove the excess adhesive and refinish as necessary.

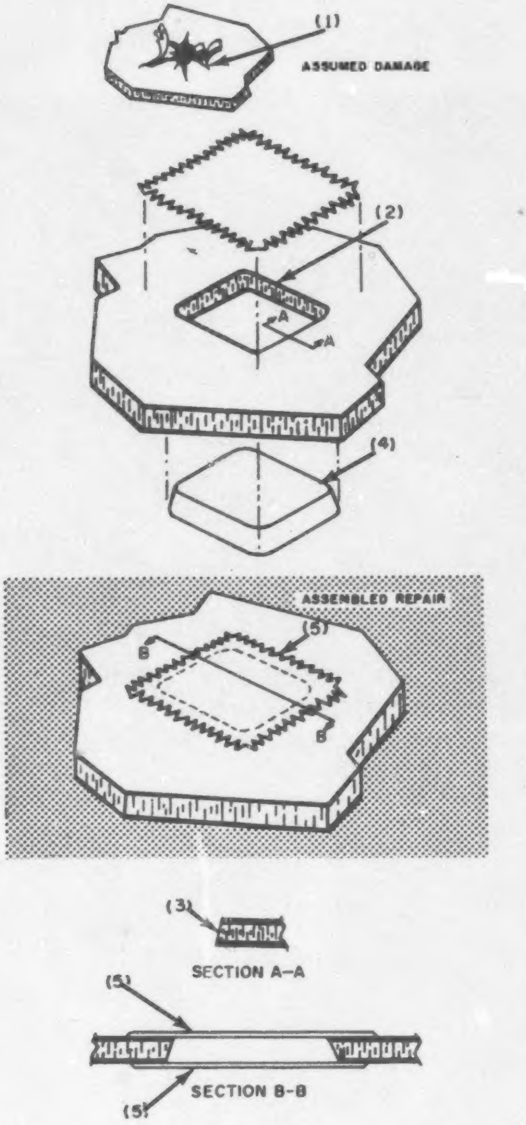
The repair shown in figure 7-19 (B) is used when a puncture through one skin facing has caused extensive damage to the honeycomb core. When the core has been damaged extensively the damaged material must be replaced.

Prepare the assembly as previously described. Cut out the damaged skin facing with a hole saw or aviation snips. File the edges of the hole smoothly. Using a pocket knife, carefully cut out the damaged core. CAUTION: Do not damage the opposite facing. Install a new core filler and complete the repair as previously described for view (A) of figure 7-19.

The repair shown in figure 7-19 (C) is used when both skin facings and the core have been damaged. Use the same procedures as described above for view (A) and (B) to facilitate this repair.

BALSA WOOD CORE.—The repair shown in figure 7-20 is used when no gain in structural strength is desired and is only to be used for sealing holes of 1 square inch or less in external surfaces. The damaged area should be cut out to a smooth circular or rectangular shape. A 3/8-inch minimum radius must be provided at the corners of rectangular cutouts.

NOTE: The afore-mentioned information applies to all repairs made to balsa wood core panels. In cutting out the damaged area, care must be taken not to separate the metal faces from the core. This can be accomplished by using a very fine-toothed coping or hacksaw blade for straight cuts, and cylindrical saws (hole saws) for cutting holes or rounding corners.



AM.360

(1) Assumed damage. (2) Damage cut out to a smooth rectangular hole. (3) Inner metal face cut back and beveled. (4) Filler plug. (5) Filler glued in place, sealed, and fabric patches applied.

Figure 7-20.—Balsa wood repair with filler plug and fabric patch.

After the damaged section has been cut out file the edges smooth using a fine cut file only. Then inspect the area for separation of the skin facing from the balsa wood core. If the facing has separated from the core, rebond the two surfaces, using the procedures outlined in the previous section on skin separation. Then complete the repair as shown in figure 7-20.

Figure 7-21 illustrates one flush type balsa wood core repair that is used on puncture damages larger than 1 inch. To facilitate this type repair, cut out the damaged area as previously described. After the damaged area has been cut out, the inner metal face is cut back 1 inch and the core material is removed. (See (3) fig. 7-21.)

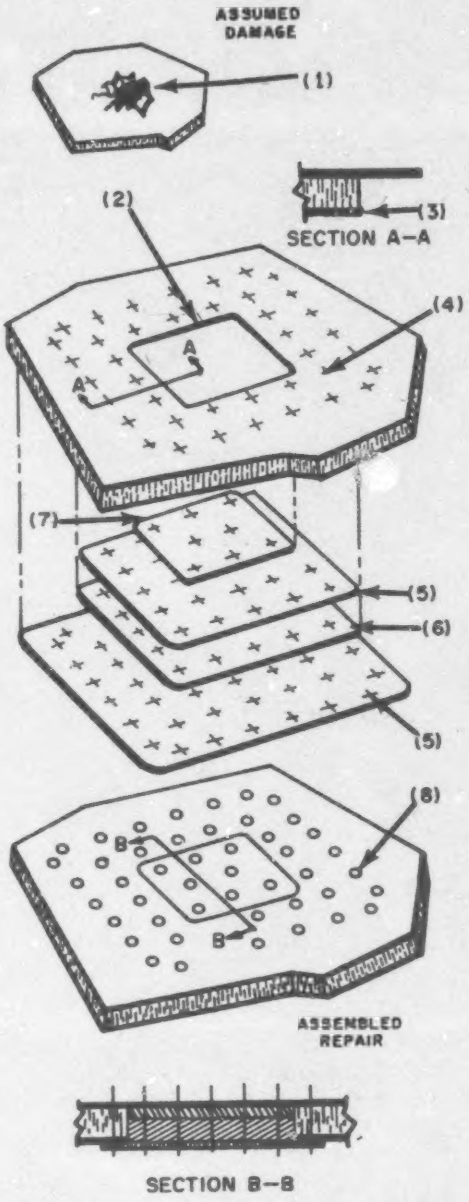
Inspect for adhesion of the face to the core and seal the exposed filler material to prevent the entry of moisture. Lay out the required rivet pattern and drill pilot holes in the panel. (See (4) fig. 7-21.) NOTE: The rivet size, rivet spacing, and number of rows of rivets are given in the appropriate repair section of the applicable Structural Repair Manual.

Next, prepare two patch plates; a wood, plywood, or phenolic filler; and a metal filler. (See (5) fig. 7-21.) The outer patch plate should fill the hole in the core, and the inner patch plate should overlap the hole in the core approximately 1 inch for each row of rivets.

Locate the patch plates and wood filler. Using the pilot holes in the panel as a guide, drill pilot holes through the patch plates and wood filler. The patch plates and wood filler are then bonded to the panel using the specified adhesive. Next, locate the metal filler and drill pilot holes through both patch plates and the wood filler.

All pilot holes are then size drilled, and machine or press countersunk, as applicable. Complete the repair by installing the specified rivets.

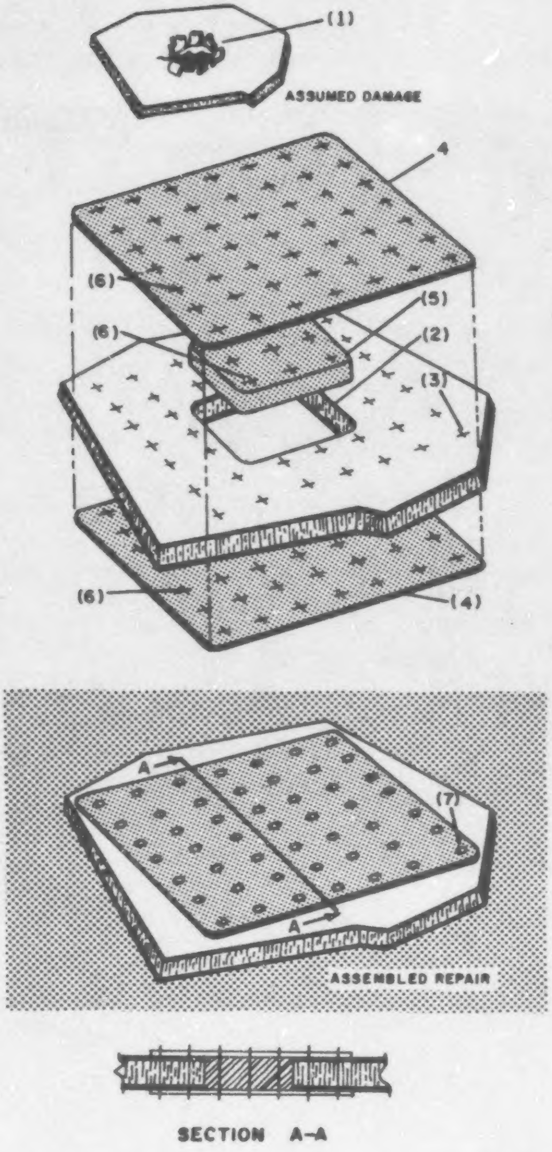
When aerodynamic smoothness is not desired, a nonflush patch such as the one shown in figure 7-22 can be used. Notice that this type repair utilizes two patch plates, a wood filler, and nonflush rivets. Otherwise, the procedures described for the repair shown in figure 7-21 are applicable to this type repair.



AM.361

(1) Assumed damage. (2) Damage cut out to a smooth rectangle. (3) Inner metal face cut back and core removed. (4) Rivet pattern. (5) Patch plates. (6) Wood, plywood, or phenolic filler. (7) Metal filler. (8) Flush rivets installed.

Figure 7-21.—Balsa wood repair with flush patch.



AM.362

(1) Assumed damage. (2) Damage cut out to a smooth rectangle. (3) Rivet pattern. (4) Nonflush patch plates. (5) Wood filler. (6) Rivet patterns. (7) Nonflush rivets installed.

Figure 7-22.—Balsa wood repair with nonflush patch.

TRAILING EDGE REPAIR

A trailing edge is the rearmost edge of an airfoil (wing, flap, rudder, elevator, etc.). It may be a formed or machined metal strip or possibly a metal covered honeycomb or balsa wood core material which forms the shape of the edge by tying the ends of a rib section together and joining the upper and lower skins. These trailing edges are very easily damaged. The majority of this type damage can be avoided if care is taken when moving aircraft in confined spaces, and/or when positioning ground support equipment around parked aircraft.

NOTE: The trailing edges on some high performance aircraft are almost knife edge in construction. Extreme care must be taken when working around these surfaces to avoid personnel injury.

The following paragraphs briefly describe the procedures to be used in repairing damage to both the all metal and sandwich construction trailing edges.

ALL METAL

Trailing edge repairs to all-metal construction assemblies and/or control surfaces are performed using basically the same procedures outlined in section one of this chapter, titled "Damage Repair Procedures."

The lap or flush patch may be used, depending on the size of the damage, type aircraft, and the assembly or control surface to be repaired.

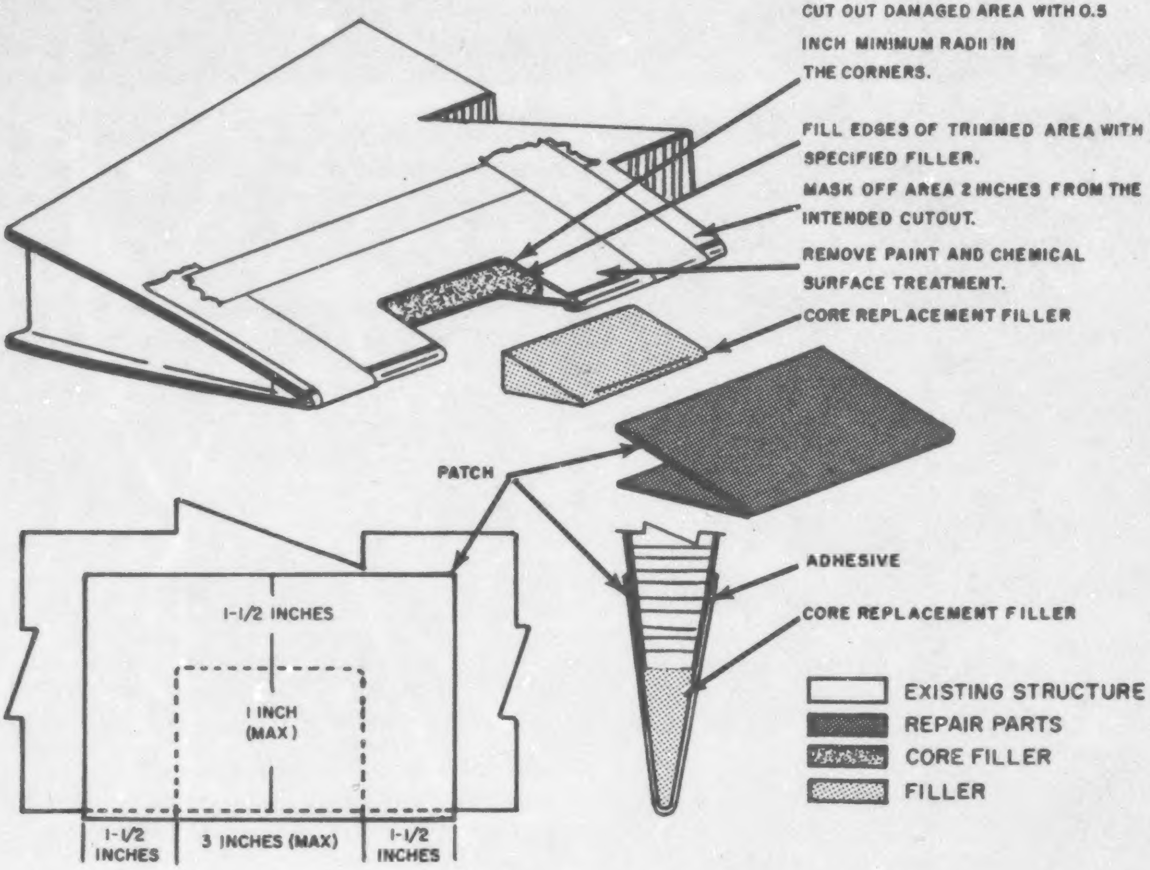
NOTE: Normally, the flush patch is used on control surfaces to insure aerodynamic smoothness.

SANDWICH CONSTRUCTION

A typical trailing edge repair to a sandwich construction assembly is shown in figure 7-23.

RIVETING PROCEDURES

The AMS must use his knowledge, ability, and experience when planning an aircraft structural repair. This does not end after the proper materials have been selected. Each type of rivet must be selected and driven in a precise manner to meet riveting specifications. Some of the


CUT OUT DAMAGED AREA WITH 0.5 INCH MINIMUM RADII IN THE CORNERS.
FILL EDGES OF TRIMMED AREA WITH SPECIFIED FILLER.
MASK OFF AREA 2 INCHES FROM THE INTENDED CUTOUT.
REMOVE PAINT AND CHEMICAL SURFACE TREATMENT.
CORE REPLACEMENT FILLER
PATCH
ADHESIVE
CORE REPLACEMENT FILLER
1-1/2 INCHES
1 INCH (MAX)
1-1/2 INCHES
3 INCHES (MAX)
1-1/2 INCHES
EXISTING STRUCTURE
REPAIR PARTS
CORE FILLER
FILLER

AM.363

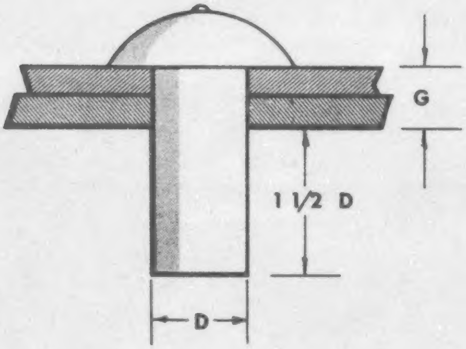
Figure 7-23.—Trailing edge repair (sandwich construction).

specifications are rivet spacing and edge distance, diameter of rivet hole, aerodynamic smoothness, and size of the rivet bucktail. These can be accomplished only through determination, practice, and accurate manipulation of all standard layout and riveting equipment.

RIVET SELECTION

The following rules govern the selection and use of rivets in making a repair:

1. Replacements must not be made with rivets of lower strength material unless they are larger than those removed. For example, a rivet of 2024 aluminum alloy should not be replaced by one made of 2017 aluminum alloy unless the 2017 rivet is a size larger. Similarly, when 2117 rivets replace 2017 rivets the next larger size should be used.
2. When rivet holes become enlarged, deformed, or otherwise damaged, use the next larger size as replacement.
3. Countersunk-head rivets are to be replaced by rivets of the same type and degree of countersink, either AN426 or MS20426.
4. All protruding head rivets are to be replaced with universal head, either AN470 or MS20470.
5. Rivets of smaller diameter than 3/32 inch will not be used for any structural parts, control parts, wing covering, or similar parts of the aircraft.



G-GRIP (TOTAL THICKNESS)
D-DIAMETER OF RIVET
1 1/2 D+G=TOTAL LENGTH OF RIVET

AM.364

Figure 7-24.—Rivet length.

6. Minimum rivet diameter is one times the thickness of the thickest sheet to be riveted.

7. Maximum rivet diameter is three times the thickness of the thickest sheet to be riveted.

8. The proper length of rivet is an important part of the repair. Should too long a rivet be used, the formed head will be too large, or the rivet may bend or be forced between the sheets being riveted. Should too short a rivet be used, the formed head will be too small or the riveted material will be damaged. The length of the rivet should equal the sum of the thickness of the metal plus 1 1/2 times the diameter of the rivet, as shown in figure 7-24. The formula for determining rivet length is specified as follows:

$$1\ 1/2\ D + G = L,$$

where D = rivet diameter, G = grip (total thickness of material), and L = total length of rivet.

SPACING AND EDGE DISTANCE

RIVET SPACING, also referred to as RIVET PITCH, is the distance between rivets in the same row, and is measured from rivet center to rivet center. TRANSVERSE PITCH is the distance between rows of rivets and is measured from rivet center to rivet center. EDGE DISTANCE is the distance from the center of the rivet to the edge of the material being riveted.

There are no specific rules which are applicable to every case or type of riveting. There are, however, certain general rules which should be followed.

Rivet Spacing

Rivet spacing (pitch) depends upon several factors, principally the thickness of the sheet, diameter of the rivets, and the manner in which the sheet will be stressed. Rivet spacing should never be less than 3D (3 times the rivet diameter). Spacing is seldom less than 4D nor more than 8D.

Transverse Pitch

When two or more rows of rivets are used in a repair job, the rivets are staggered to obtain maximum strength. The distance between the rows of rivets is called transverse pitch. Transverse pitch is normally 75 percent of existing rivet pitch but should never be less than 2 1/2D.

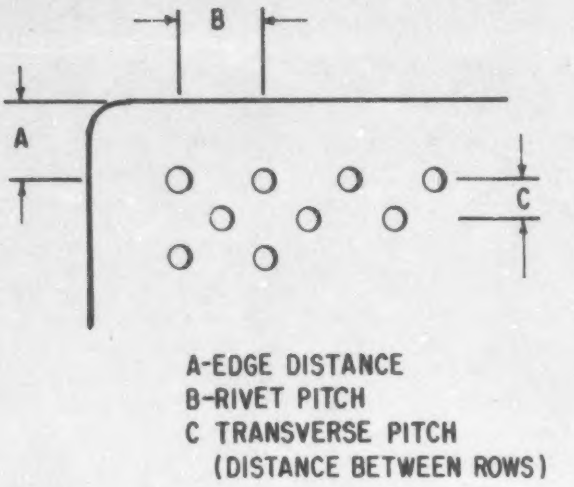
Edge Distance

Edge distance for all rivets, except those with a flush head, should not be less than 2D (twice the diameter of the rivet shank) nor more than 4D. Flush-head rivets require an edge distance of at least 2 1/2D. If rivets are placed too close to the edge of the sheet, the sheet is apt to crack or pull away from the rivets; and if placed too far away from the edge, the sheet is apt to turn up at the edge.

NOTE: On most repairs, the general practice is to use the same rivet spacing and edge distance that the manufacturer used in the surrounding area, or the Structural Repair Manual for the particular aircraft may be consulted. Figure 7-25 illustrates rivet spacing and edge distance.

DRILLING RIVET HOLES

Standard twist drills are used for drilling rivet holes. Table 7-1 specifies the size drill for the



AM.365

Figure 7-25.—Rivet spacing and edge distance.

Table 7-1.—Drill sizes for various size rivets.

Rivet diameter	Drill size	Drill size
3/32	No. 41	0.0960
1/8	No. 30	.1285
5/32	No. 21	.1590
3/16	No. 11	.1910
1/4	No. F	.2570
5/16	No. P	.3230
3/8	No. W	.3860

various size rivets. Note that there is a slight clearance in each case, which prevents binding of the rivet in the hole.

Locations for the rivet holes should be center-punched and the drilling done with a power drill, either electric or pneumatic. Electric drills constitute a fire hazard when drilling on or near an aircraft due to the arcing of the brushes, therefore, the pneumatic drill must be used. The center-punch mark should be large enough to prevent the drill from slipping out of position, but must not be made with enough force to dent the surrounding material. (See fig. 7-4.) The drilling can be done with a hand drill if no power drill is available. All burrs must be removed before riveting by using a larger size drill, or by using a deburring tool.

Use of Portable Drills

Before using a drill, turn on the power and check it for trueness and vibration. Do not use a drill bit that wobbles or is slightly bent. Trueness may be visibly checked by running the motor freely.

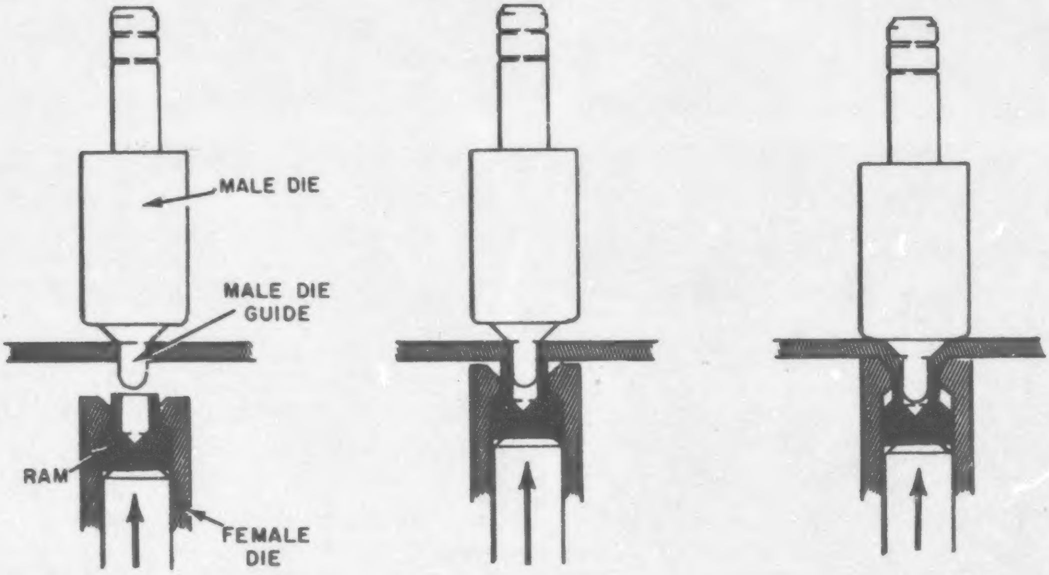
The most common error made by the inexperienced man is to hold a portable drill at an incorrect angle to the work. Make sure the drill is held at right angles to the work. When drilling in a horizontal position, it can be seen if it is too far to the right or left, but it is difficult to tell if the rear of the drill is too high or too low. Until the AMS learns how to hold a drill at the correct angle, he should have another man sight the angle before starting the drill.

Another common mistake is to put too much pressure on the drill. Pushing or crowding a drill may break the drill point, cause the drill to plunge through the opposite side of the sheet, leaving rough edges around the hole, or cause the drill to side slip on the metal causing hole elongation.

The drill should not be stopped immediately upon breaking through, but should be inserted for approximately half its length while still running, and then withdrawn. This operation requires judgment and skill since it is very easy to ream the hole oversize; but if this is done properly, cleaner holes will result.

FLUSH RIVETING

Progression has been made possible towards higher speed aircraft by improved design,



AM.336

Figure 7-26.–Dimple countersinking.

stronger and lighter aluminum alloys, and more powerful engines. Attention has been turned towards the elimination of protruding head rivets on the exterior surfaces of aircraft. In fabricating stressed metal skin on modern aircraft, all exposed rivet heads must be countersunk to lie flush with the outer surface of the skin. It is essential to provide an aerodynamically smooth surface.

Flush rivets are more difficult to install, since the parts being riveted must be countersunk, which is one extra operation following drilling. Another hazard is the closeness of the rivet set to the metal during riveting. If considerable skill is not used, the metal will be damaged by the rivet set. Flush rivets are made with heads of several different angles, but the 100-degree rivet is standard for all Navy aircraft.

The two methods used in countersinking for flush riveting are dimple and machine countersinking. In some instances, a combination of the two may be used; in other words, the top sheet of an assembly may be dimpled while the under sheet is machine countersunk.

Dimple Countersinking

Dimple countersinking is accomplished by using male and female dies (fig. 7-26). The female die shown in figure 7-26 has incorporated in it a spring-loaded ram which flattens the bottom of the dimple as it is formed. This prevents cracks from forming around the dimple. The forming of a dimple is a combined bending and stretching operation. A circular bend is formed around the hole. As in any bending operation, the tension force at the upper side of the bend (break) creates the radius at the junction of the two surfaces–the top side of the sheet and downward bent inner wall of the dimple depression. The stretch occurs around the hole as it is displaced from its original position and relocated at the bottom of the dimple. The female die must have a slightly larger cone diameter than the corresponding dimension of the male die. This allows for material thickness and to relieve the bending load at the break in order to avoid circumferential cracks around the boundaries of the dimple. As a further safeguard, a slight radius is

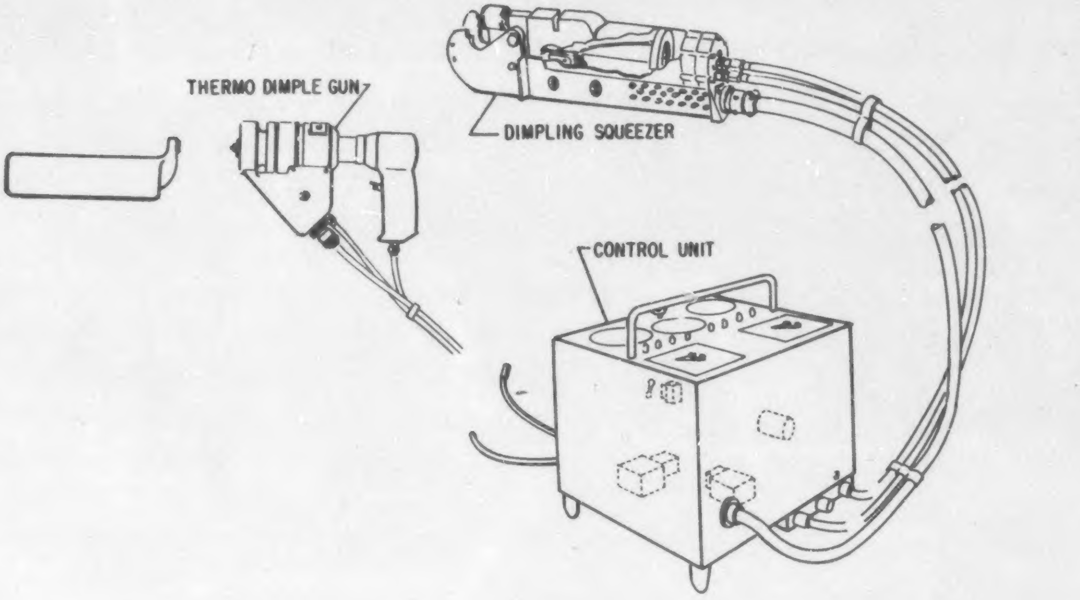


Figure 7-27.—Hot dimpling kit.

made on the female die at the junction of the top face with the dimple depression.

Dimpling dies are made to correspond to any size and degree of countersunk rivet head available. The dies are numbered, and the correct combination of dies to use is indicated in charts specified by the manufacturer. Both male and female dies are machined accurately and have highly polished surfaces. When dimpling a hole, place the material on the female die and insert the male die in the hole to be dimpled. The dies are generally brought together, forming the dimple by a mechanical or pneumatic force.

HOT DIMPLING.—As newer aluminum alloys were developed to increase the shear and tensile strength, they became increasingly difficult to form, since these alloys are harder and more brittle. These aluminum alloys are subject to cracking when formed or dimpled cold. For this reason, it is necessary to use a hot dimpling process. The application of hot dimpling to the more brittle materials is advantageous for the reduction of cracking and also from the standpoint of dimple shape. The heat is applied to the material by the dies, which are maintained at a specific temperature by electrical heaters. The heat is thus transferred to the material to be dimpled only momentarily and none of the heat-treat characteristics of the material are lost.

There are several models of dimpling machines used in the Navy, from the bulky floor models to portable equipment. One of the most popular portable types is shown in figure 7-27. Basically, it has three units—the dimpling control unit, dimpling squeezer, and the thermo dimple gun.

The dimpling control unit is a small compact unit designed to regulate automatic control dimple die temperatures, prepressure, dwell time, and final forming pressure. This same unit is used with both the hot dimpling squeezer and the thermo dimple gun.

Table 7-2.—Dwell time chart.

Equipment	Material	Tool-temperature
AT259 Portable squeezer	7075S-T6	MALE—650° F FEMALE—650° F

AN426-100° Rivets

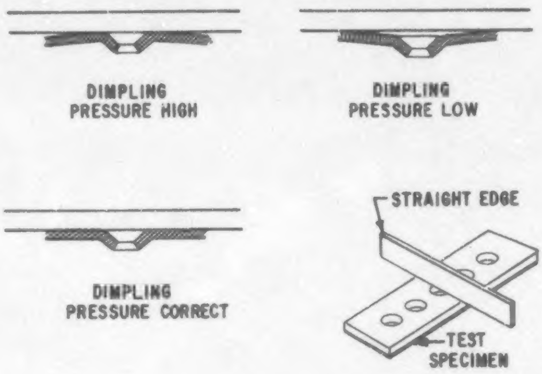
Material thickness			.016	.020	.025	.032	.040	.051	.064	.072	.081	.091
Size	Die numbers											
	Male	Female										
3/32	AT252DA-3	AT251DA-3	1.5 15	1.5 15	1.5 15	1.5 15	1.75 20	1.75 30	1.75 30			
1/8	AT252DA-4	AT251DA-4	1.5 15	1.5 15	1.5 15	1.5 15	1.5 20	2.0 20	2.0 30	2.0 35		
5/32	AT252DA-5	AT251DA-5	1.5 15	1.5 15	1.5 15	1.5 15	1.5 20	1.5 30	2.0 35	2.25 40		
3/16	AT252DA-6	AT251DA-6	1.5 15	1.5 15	1.5 15	1.5 15	1.25 20	2.0 30	2.0 35			
1/4	AT252DA-8	AT251DA-8	1.5 15	1.5 15	1.5 15	1.5 15	1.25 25	1.5 30				

Key to chart: Dwell time in seconds. Dwell pressure in pounds.

The hot dimpling squeezer is specially designed for use where stationary squeezer operation is impractical and some times impossible. It is capable of working all material gages up to and including 0.091 inch. The squeezer type is designed to dimple in areas that are inaccessible to other types of equipment. Male and female dies are independently heated by heaters operated from an electrical source. The heaters produce a short heat-up and recovery time. The male die is adjustable for maximum squeeze for all gages of material. Also incorporated is a cooling feature which affords ease of handling and also reduces the power loss due to heat interference.

The thermo dimple gun is used to dimple in the center of panels and in those areas otherwise inaccessible to yoke type dimpling equipment. When being used on the aircraft, the thermo dimple gun drives the dimple from the exterior while the female die and dolly bar are used on the inside. The thermo dimple gun is aircooled, eliminating the need for cumbersome heat-resistant gloves. This tool is small, compact, well balanced, and easy to handle.

Operation of the Hot Dimpler.–Prior to setting the dimpling control unit up for dimpling, the AMS should refer to the equipment manufacturer's dwell time chart. (See table 7-2.) Select the proper chart, taking into consideration which type of equipment is to be used and the material to be dimpled. Notice in table 7-2 the type of equipment is a portable squeeze type and the material being dimpled is 7075S-T6. The temperature required for both the male and female dies is 650°F. The second line indicates the rivet to be used, in this case, 100 degree countersink rivet. The third line indicates the gage of material to be dimpled. The lower left side of the chart indicates the diameter of rivet to be used and part numbers of both the male and female dies. The chart is used in this manner: If 0.040 material was being dimpled, using 1/8 inch diameter rivets, the AMS should draw an imaginary line down the 0.040 column and across the chart on the 1/8-rivet size line. At the point where the two imaginary lines cross is the information block denoting the required dwell time in seconds and dwell pressure in pounds. In this case the dwell time is 1.5 seconds and the dwell pressure is 20 pounds.



AM.368

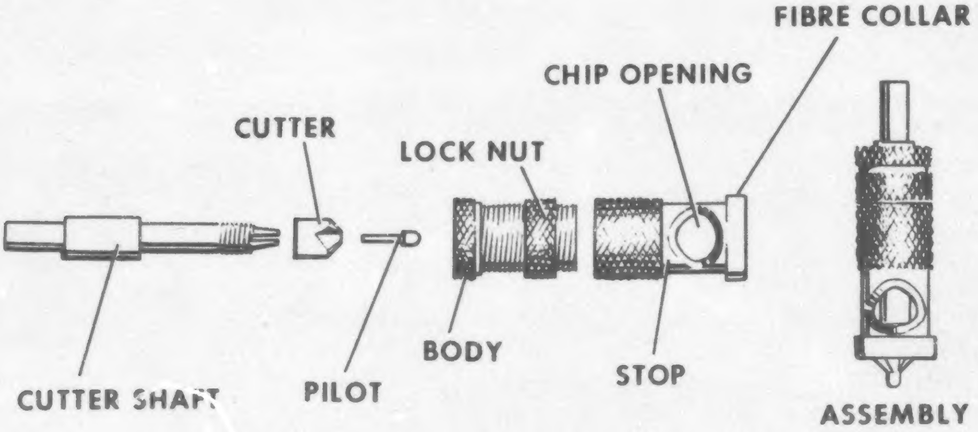
Figure 7-28.—Checking dimple equipment air pressure.

When setting up any dimpling equipment, follow the step-by-step procedure outlined in the Operating and Maintenance Manual supplied with the equipment. Since equipment types vary, it is impractical to specify a standard procedure in this course. However, there are four general requirements of a dimple, and by examining each, it is possible to denote improper setting up of equipment.

1. Sharpness of definition. It is possible to get a dimple with a sharp break from the surface into the dimple. The sharpness of the break is controlled by two things (1) amount of pressure and (2) material thickness.

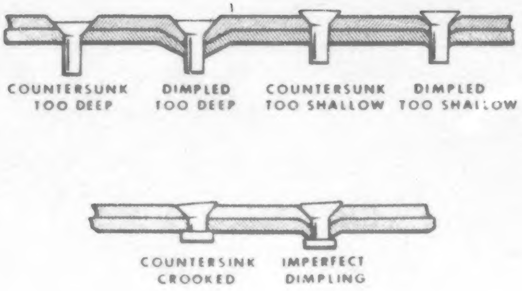
2. Condition of dimple. The dimple must be checked for cracks or flaws that might be caused by damaged or dirty dies, or by improper heating.

3. Warpage of material. The amount of warpage may be held to a minimum if the correct pressure setting is held. When dimpling a strip with too much pressure, the strip tends to form a convex shape as shown in figure 7-28. When insufficient pressure is used it tends to form a



AM.369

Figure 7-29.—Stop-type countersink.



AM.370

Figure 7-30.—Incorrect countersinking.

concave shape. This can be checked by using a straight edge.

4. General appearance. The dimple should be checked with the fastener that is to be used, making sure it meets the flushness requirement. This is important as the wrong type or size dies are sometimes used by mistake.

Machine Countersinking

Machine countersinking is used for flush riveting all sheet 0.064 inch and greater in thickness. A countersink has a cutting face beveled to the angle of the rivet head and is kept centered by a pilot shaft inserted in the rivet hole. A stopping device automatically acts as a depth gage so that the hole will not be countersunk too deep. Figure 7-29 shows a stop-type countersink.

The countersink should always be equipped with the fiber collar shown in figure 7-29, to prevent marring of the metal surface. A hand, electric, or air drill may be used to operate the countersink, and should not be operated above 2,500 rpm. The countersink must be sharp to avoid vibration and chatter. Figure 7-30 illustrates several effects of incorrect countersinking.

RIVET DRIVING PROCEDURE

Before driving any rivets, make sure all holes line up perfectly, all shavings and burrs have been removed, and the parts to be riveted are fastened securely together. It is important that the sheets be held firmly together in the immediate area of the rivet being driven.

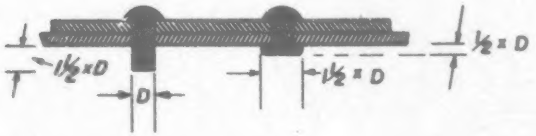
To adjust the speed of the gun, place it against a block of wood. Never operate a rivet gun without resistance against the set, as the vibrating action may cause the retaining spring to break, allowing the set to fly out.

CAUTION: A rivet set can be a deadly weapon. If a rivet set is placed in a rivet gun without a set retainer and the throttle of the gun is opened, the rivet set may be projected like a bullet. This may cause either severe injury to a person or the destruction of equipment.

The gun should be adjusted so that the rivet may be driven in the shortest possible time, but care must be taken not to drive the rivet so hard or in such a manner as to dimple the metal. Practice will enable one to properly adjust a gun for any type of work.

When the rivet has been pushed into proper position and held there firmly with the set of the rivet gun resting squarely against the rivet head, the bucking bar is held firmly and squarely against the protruding rivet shank. (In most instances, the bucking bar must be manipulated by another man, called the bucker.) The gunner then exerts pressure on the trigger and starts driving. The gun must be held tightly against the rivet head and must not be removed until the trigger has been released.

The bucker removes the bucking bar and checks the upset head after the gunner has stopped driving. A signal system is usually employed to develop the necessary teamwork and consists of tapping lightly against the work. One tap may mean "not fully driven, hit it again"; two taps may mean "good rivet"; three taps may mean "bad rivet, remove and drive another"; and so on.



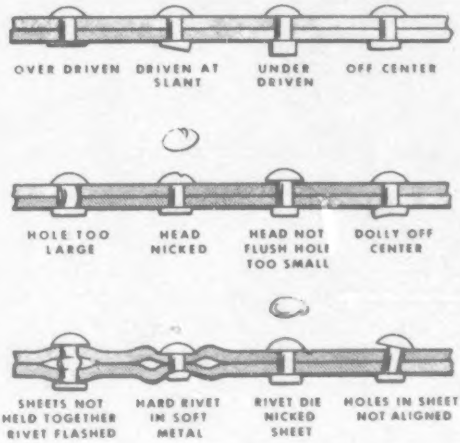
AM.371

Figure 7-31.—Rivet dimensions before and after bucking.

The upset head, often referred to as the bucktail, should be one and one-half times the original diameter of the original shank in width and one-half times the original diameter in height as shown in figure 7-31. If the head thus formed is narrower and higher than the dimensions given, more driving is necessary. If it is wider and shallower, it must be removed and replaced.

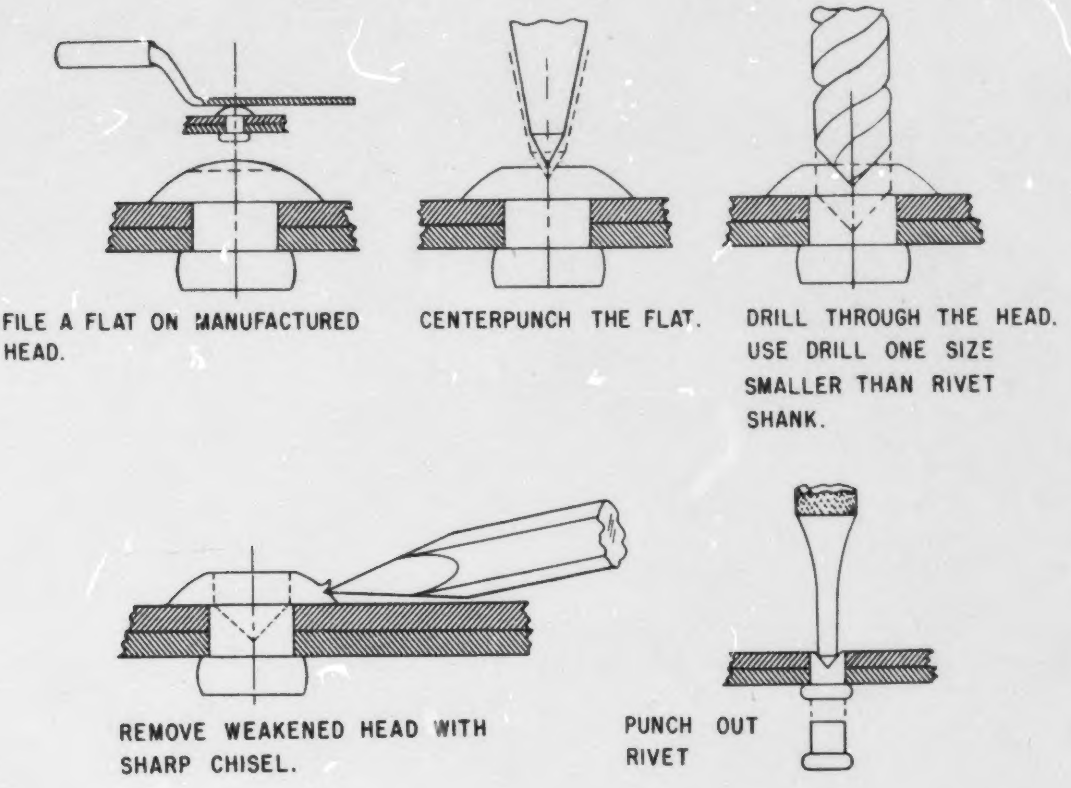
RIVET REMOVAL

Rivets must be removed and replaced if they show even the slightest deformity or lack of alignment. Among the reasons for replacing rivets are the following: Rivet marred by bucking bar or rivet set; rivet driven at slant, or shank bent over; rivet too short, causing head to be shallow; rivet pancaked too flat from overdriving; sheets spread apart and rivet flashed between sheets; rivet driven too lightly, causing sheets to buckle; two rivet heads not in alignment; and head of countersunk rivet not flush with outside surface or driven below surface. Examples of these incorrectly driven rivets are shown in figure 7-32.



AM.372

Figure 7-32.—Incorrectly driven rivets.

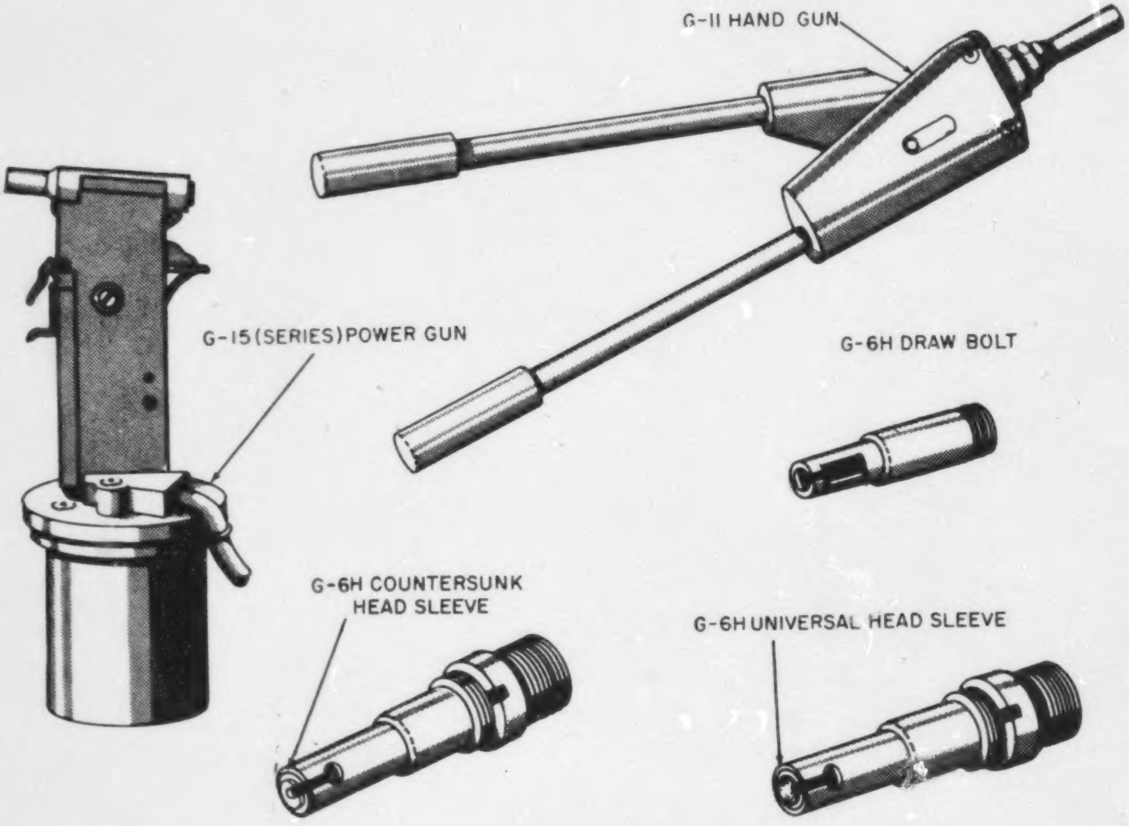

FILE A FLAT ON MANUFACTURED HEAD.
CENTERPUNCH THE FLAT.
DRILL THROUGH THE HEAD. USE DRILL ONE SIZE SMALLER THAN RIVET SHANK.
REMOVE WEAKENED HEAD WITH SHARP CHISEL.
PUNCH OUT RIVET

AM.373

Figure 7-33.—Removal of rivets.

When removing rivets, care should be taken not to enlarge the rivet hole, as this would necessitate the use of a larger size rivet for replacement. To remove a rivet, file a flat surface on the manufactured head if accessible. It is always preferable to work on the manufactured head rather than on the one that is bucked, since the former will always be more symmetrical about the shank. Indent the center of the filed surface with a center punch and use a drill of slightly less than shank diameter to drill through the rivet head. Remove the drill and, with the other rivet end supported, shear the head off with a sharp chisel. Always cut along the direction of the plate edge. If the shank is unduly tight after the removal of the head, the shank should be drilled out. However, if the sheet is firmly supported from the opposite side, the shank may be punched out with a drift punch. (See fig. 7-33.)

The removal of flush rivets requires slightly more skill. If the formed head on the interior is accessible and has been formed over heavy material such as an extruded member, the formed head can be drilled through and sheared off, as mentioned above. If the material is thin, it may be necessary to drill completely through the shank of the rivet and then cut the formed head with diagonal cutting pliers. The remainder of the rivet may then be drifted out from the inside.



AM.374

Figure 7-34.—Self-plugging rivet (friction lock) installation tools.

BLIND RIVET INSTALLATION

The description and use of blind rivets are covered in chapter 6. The special tools and installation and removal methods are covered in the following sections. Selection of the proper equipment depends on a number of variables; space available for equipment, type of rivets to be driven, availability of air pressure, etc.

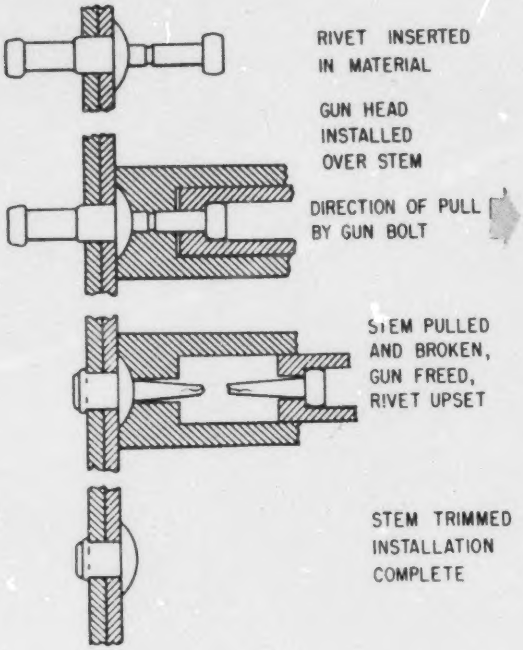
Installation Tools for Friction Lock Rivets

The guns used for installing this type of self-plugging rivet are the G-11 hand gun and the G-15 (series) and G-40 (series) power guns. The G-15 power gun uses G-6H pulling heads as does the G-11 hand gun. The G-40 power gun uses the H-40 pulling heads primarily; however, through the use of a 226 adapter, G-6H heads may be used. Extensions are available for all guns using G-6H heads. Figure 7-34 shows the G-11 and G-15 rivet guns with the G-6H pulling heads.

The heads are manufactured in three different sizes to accommodate the different rivet diameters. For ease of selection, the sizes are stamped on the parts of the pulling head.

Installation Procedures

It is important that the proper drawbolt and sleeve be used for the rivet being installed. The drawbolt should correspond to the diameter of



AM.375

Figure 7-35.—Self-plugging rivet (friction lock) installation.

the rivet, and the sleeve should correspond to the rivet diameter and head style. Speed of installation may be increased by inserting a number of rivets in the work and then applying the gun. In other instances, such as overhead work, it is apparent that this method would be impractical and the rivet should be loaded into the gun and then inserted into the prepared hole. The rivet must be completely inserted into the slot in the drawbolt, because improper seating of the rivet may permit the head to break off before the rivet is properly set. (See fig. 7-35.) When using a hand gun, hold the rigid handle of the gun parallel to the rivet axis. Open the movable handle as far as it will go, then partially close. Repeat this operation until the rivet stem breaks, then release the gun by completely closing the movable handle. When using the power gun, hold the head of the gun parallel to the axis of the rivet. Push the gun against the work with enough force to seat the head of the rivet firmly, and to insure contact between the parts being riveted. Pull the trigger until the stem breaks. The stem will be ejected through the rubber tube at the back of the gun head. It is important that this tube be in place in order to prevent stems from getting into the gun mechanisms.

Inspection

The rivet is satisfactory if the pin is firm and the head is seated tightly on the face of the material. Occasionally, the head will rise slightly in the area which was under the slot of the pulling head. This condition is acceptable if the head is not too badly deformed and the tension characteristics of the joint are not made critical by the deformation of the head. Figure 7-36 illustrates satisfactory and unsatisfactory self-plugging rivets.

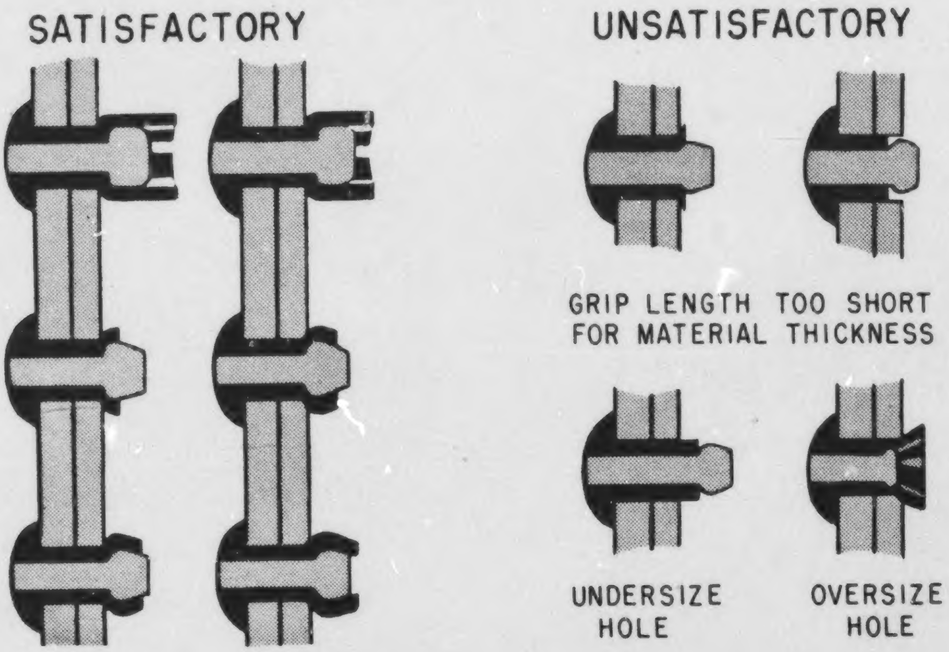
Removal

These rivets are removed in much the same manner as the common, solid shank rivets, except for the preliminary step of driving out the rivet stem. (See fig. 7-37.)

1. Punch out the rivet stem with a pin punch.
2. Drill out the rivet head, using a drill slightly smaller than the rivet shank.
3. Pry off the weakened rivet head with a pin punch.
4. Push out the remainder of the rivet shank with a pin punch. If the shank will not push out, drill the shank, taking care not to enlarge the hole in the material. If the hole should be enlarged, finish-drill for an oversize rivet.

Installation Tools for Mechanical Lock Rivets

One of the tools used for driving these rivets is the CP350 blind rivet pull tool. (See fig. 7-38.) The nose of the tool includes a set of chuck jaws which fit the pull grooves in the rivet pin and pull it through the rivet shank to drive the rivet; an outer anvil which bears against the outer part of the manufactured head during the driving operation; and an inner anvil which advances automatically to drive the locking collar home



AM.376

Figure 7-36.—Inspection of self-plugging rivets (friction lock).

after the blind head is formed. A short nose assembly, interchangeable with the standard assembly, is available for use in areas where there is not sufficient clearance for the standard nose.

A change in rivet diameter requires a change in chuck jaws, outer anvil, inner anvil, inner anvil thrust bearing, and an adjustment of the shift valve operating pressure as described below. A change in the rivet head type from universal head to countersunk head, or vice versa, requires a change of the outer anvil only, if there is no change in the rivet diameter.

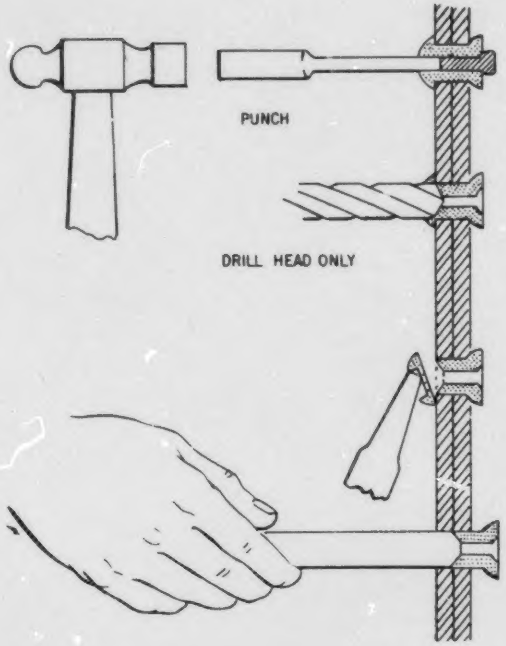
A special chuck jaws assembly tool is furnished with the tool. To facilitate insertion of the chuck jaws into the chuck sleeve, mount the three jaws on this assembly to form a cone, and lower the inverted chuck sleeve over the jaws.

Always be sure that the pull tool is equipped with the correct size chuck jaws, outer and inner anvils to fit the rivets being driven, and that the relief valve operation pressure is properly adjusted for the size rivets being driven. Also make sure that the rivets are of proper length. The tool has only one operating adjustment. This adjustment is used to control the pull on the pin at which the inner anvil advances. The desired amount of the pull depends on the diameter of the rivets to be installed, and the pull is varied by changing the pressure at which the adjustable shift valve operates. To adjust, proceed as follows:

1. Remove pipe plug from tool cylinder and connect a pressure gage to the tool.

2. Press trigger and release it the instant a puff of exhaust indicates that the shift valve controlling the inner anvil has shifted. The gage will then indicate the shift pressure. See table 7-3 for the approximate pressures.

NOTE: The trigger must be released immediately as the valve shifts. Otherwise the gage



AM.377

Figure 7-37.—Removal of self-plugging rivets (friction lock).

will record the higher pressure which builds up as soon as the valve has shifted.

3. To adjust the pressure, loosen the valve-adjusting screw locknut and turn the valve-adjusting screw clockwise to increase pressure, or counterclockwise to decrease pressure, until the desired pressure is obtained. Check the pressure after tightening the valve-adjusting screw locknut. When rivets of extremely long grip length are to be driven an adjustment to the high pressure limit should be made. For efficient operation of the tool, the minimum desired line pressure should be not less than 90 psi and the maximum not more than approximately 110 psi. When using a CP350 A or B rivet pull tool, it may be necessary to increase the inside diameter of the air inlet bushing, part number 81479, from 0.055 to 0.065 inch when driving 3/16-inch diameter rivets if the line pressure is below 90 psi. When driving 1/8-inch diameter rivets, it may be necessary to use air inlet bushing, part number 82642, having a 0.040-inch inside diameter. If the tool "flutters," cut down the line pressure to 60 psi with an air regulator, part number 900-102, attached to the air inlet bushing. When using a CP350C rivet pull tool to drive 1/16- and 5/32-inch diameter rivets, use air inlet bushing, part number 81479, and shift valve stop, part number 83731. When driving 1/8-inch diameter rivets, use air inlet bushing, number 83642, and cut down the line pressure to 60 psi with air regulator, part number 900-102, attached to the air inlet bushing.

Installation Procedures

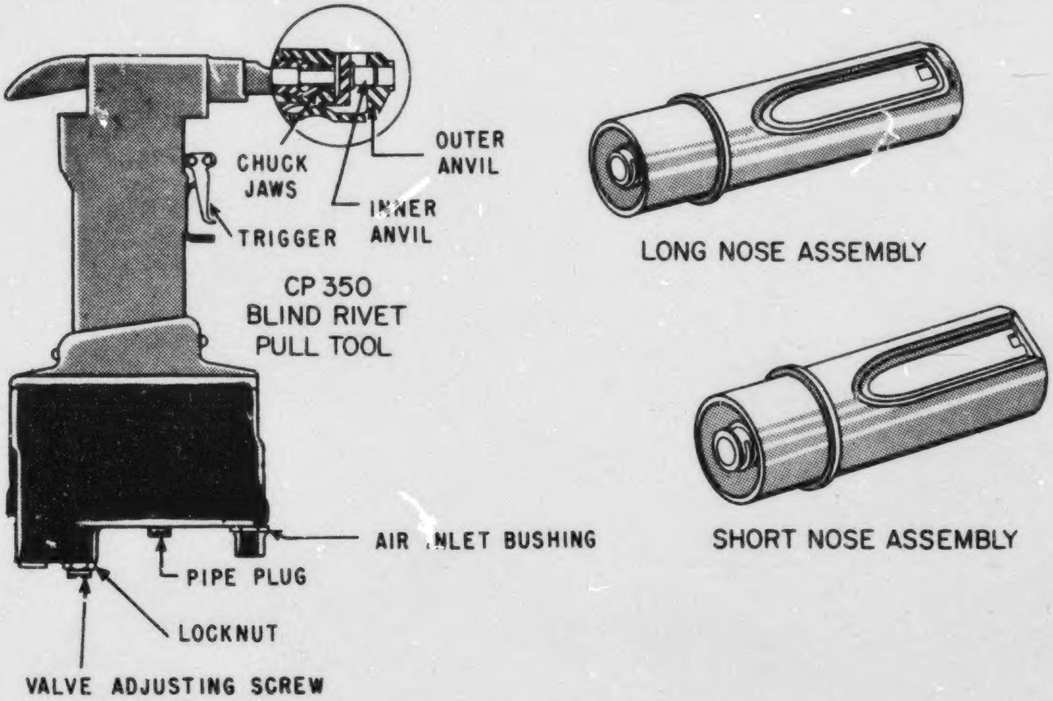
Proper driving procedures are vital to obtain a firm joint. The recommended procedures are as follows:

1. Hold the head of the gun steady and at right angles to the work.
2. Press on the head of the gun hard enough to hold the rivet firmly against the work. Do not use a great amount of pressure unless necessary to bring the part being riveted into contact.
3. Squeeze the gun trigger and hold until the rivet pin breaks, then release the trigger. The next rivet should not be driven until the return action has caused the gun to latch. A distinct click will be heard, indicating that the gun is ready for the next installation cycle.

Figure 7-39 shows the complete installation of a self-plugging (mechanical lock) rivet.

The rivet is actually cold-squeezed by the action of the pin head drawing against the hollow shank end. Shank expansion through the action of the extruding angle, blind head formation, and setting of the mechanical lock in the rivet head all follow in automatic sequence and require but a fraction of a second. In some places such as near the trailing edge of a control surface, there may not be sufficient space between the two surfaces to insert the rivet.

In such cases, the pin may be forced into the hollow shank until the head of the pin just touches the end of the shank. Since no further shank expansion will result, the drill hole should not be enlarged to provide a free fit of the already expanded rivet. To insert the rivet, use a hollow drift pin which will accommodate the rivet pin and the locking collar. (See fig. 7-40.)



AM.378

Figure 7-38.—Self-plugging rivet (mechanical lock) pull tool.

Table 7-3.—Adjustments for CP350 blind rivet pull tool.

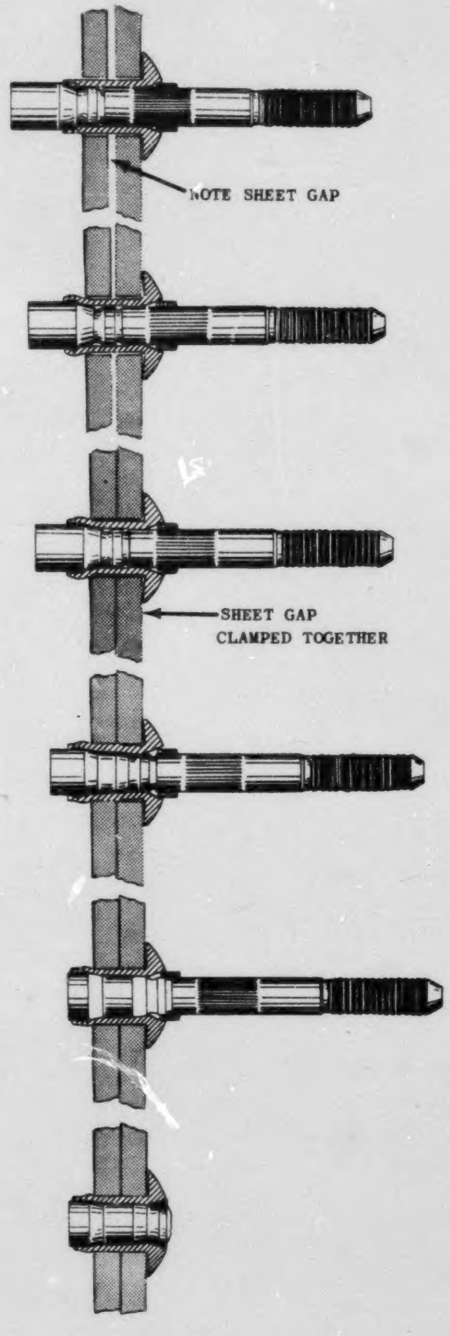
Rivet diameter	Shift valve operating pressure
1/8	30 to 31 psi
5/32	46 to 47 psi
3/16	66 to 67 psi

This allows a driving force to be exerted on the head of the rivet. Drive the head into firm contact with the sheet and then apply the rivet pull tool in the usual manner to upset the rivet.

Due to the mechanical lock feature of the pin and sleeve, the driven rivet is substantially the mechanical equivalent of a one-piece solid rivet. The mechanical lock feature increases the load-carrying capacity in single shear from about 10.3 percent in the case of thick sheets where joint strength is considered critical in rivet shear, to as much as 63.3 percent in thin sheets where sheet bearing is considered critical.

Inspection

Visual inspection of the seating of the pin in the manufactured head is the most reliable and simple means of inspection. If the proper grip length has been used and the locking collar and broken end of the pin are approximately flush with the manufactured head, the rivet has been properly upset and the lock formed. Insufficient grip length would be indicated by the pin breaking below the surface of the manufactured head, and excessive grip length would be indicated by the pin breaking off well above the manufactured head. In either case, the locking collar might not be properly seated, thus forming an unsatisfactory lock. Table 7-4 gives limits for proper pin seating.



(1) Mechanical-lock rivet before installation. Note shorter stem on blind side providing marked improvement for limited blind clearance applications.

(2) As the stem is pulled into the rivet sleeve, it immediately forms the blind head. The mechanical-lock always forms the blind head firmly against the blind sheet.

(3) Continued movement of the stem pushes the blind sheet ahead of the blind head until the sheets are firmly clamped together and the rivet is firmly seated.

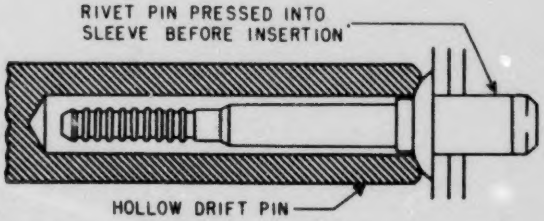
(4) The plugging portion of the stem expands the rivet sleeve to fill the hole and reduces in diameter as it passes through the rivet sleeve, providing excellent hole fill —even in oversize holes.

(5) The movement of the stem is stopped by the pulling head at a point where the groove in the stem and the chamfer in the rivet line up to make a receptacle for the locking ring.

(6) The pulling head shifts automatically, inserts the positive mechanical locking ring, and fractures the stem flush with the rivet head.

AM.316

Figure 7-39.—Self-plugging rivet (mechanical lock).



AM.379

Figure 7-40.—Inserting self-plugging rivet (mechanical lock).

Table 7-4.—Inspection criteria for self-plugging rivets (mechanical lock).

Rivet diameter	A	B	C
1/8 inch	0.012	0.016	0.008
5/32 inch	.015	.020	.010
3/16 inch	.018	.024	.012

A. Maximum allowable distance of locking collar above or below rivet head.
B. Maximum allowable distance of top of land on pin above rivet head.
C. Maximum allowable distance of top of land on pin below rivet head.

Removal

Removal of this rivet is accomplished easily without damage to the work by use of the following procedure: (See also fig. 7-41.)

1. Shear the lock by driving out the pin, using a tapered steel drift pin not over 3/32-inch diameter at the small end. If working on thin material, back up the material while driving out the pin. If inaccessibility prohibits this, partially remove the rivet head by filing, or with a rivet shaver. An alternative would be to file the pin flat, center punch the flat, and carefully drill out the tapered part of the pin forming the lock.
2. Pry the remainder of the locking collar out with a drift pin.
3. Use the proper size drill to drill nearly through the rivet head. For a 1/8-inch diameter rivet, use a number 31 drill; for a 5/32, use a number 24; and, for a 3/16, use a number 15.
4. Break off the drilled head, using a drift pin as a pry.
5. Drive out the remainder of the rivet with a pin having a diameter equal to, or slightly less than, the rivet diameter.

Installation Tools for Rivnuts

Tools used in the installation of Rivnuts include the heading tool and the keyway cutter. The heading tool, as shown in figure 7-42, has a threaded mandrel onto which the Rivnut is threaded until the head of the Rivnut is against the anvil of the heading tool. This tool normally comes in three different sizes. They are identical, except for the size of their threaded mandrel. The heading tool comes in sizes 6-32, 8-32, and 10-32 which correspond with the thread sizes of the standard Rivnuts. The keyway cutter is used for cutting a notch in the Rivnut hole for the Rivnut keyway. In some instances the keyway cutter cannot be used because the material is too thick. If such is the case, use a small round file to form the keyway.

Installation Procedures

The drilling of holes for Rivnuts requires the same precision as that required for solid shank rivets. The shank of the Rivnut must fit snugly in the hole. To obtain the best results for a flathead installation, first drill a pilot hole smaller than the shank diameter of the Rivnut, then ream to the correct size. Pilot and ream drill sizes for Rivnuts are given in table 7-5.

The application of flush Rivnuts is subject to certain limitations. For metal which has a thickness greater than the minimum grip length of the first Rivnut in a series, use the machine countersink; and for metal thinner than the minimum grip length of the first Rivnut in a series, use the dimpling process. The countersunk Rivnut should not be used unless the metal is thick enough for machine countersinking, or unless the underside is accessible for the dimpling operation. Aside from the countersinking operation, the procedure for installing a

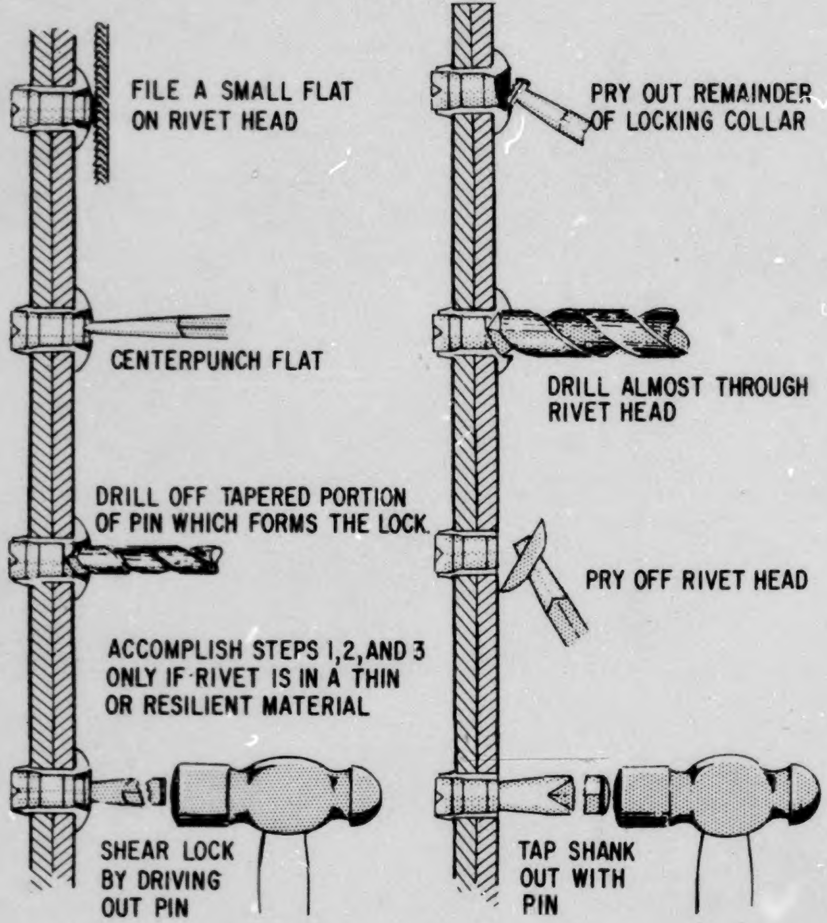
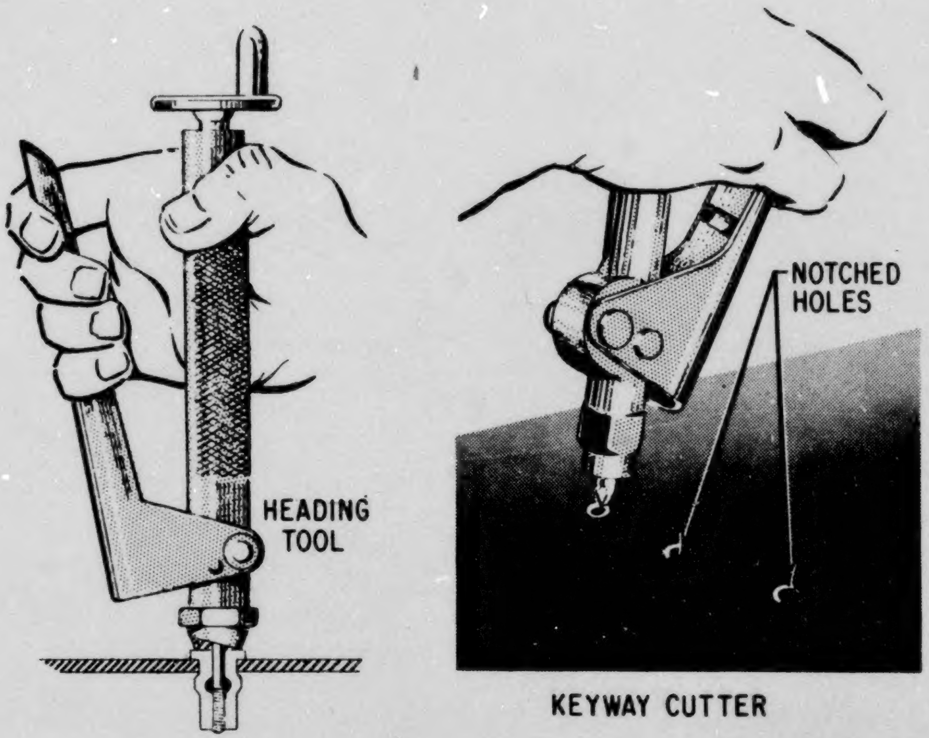

FILE A SMALL FLAT ON RIVET HEAD
CENTERPUNCH FLAT
DRILL OFF TAPERED PORTION OF PIN WHICH FORMS THE LOCK.
ACCOMPLISH STEPS 1,2,AND 3 ONLY IF RIVET IS IN A THIN OR RESILIENT MATERIAL
SHEAR LOCK BY DRIVING OUT PIN
PRY OUT REMAINDER OF LOCKING COLLAR
DRILL ALMOST THROUGH RIVET HEAD
PRY OFF RIVET HEAD
TAP SHANK OUT WITH PIN
AM.380

Figure 7-41.–Removing self-plugging rivets (mechanical lock).

flush Rivnut is the same as that for the flathead Rivnut.

When installing Rivnuts, always check the threaded mandrel of the heading tool to see that it is free from burrs and chips from the previous installation. Then screw the Rivnut onto the mandrel until the head touches the anvil. Insert the Rivnut in the hole (with the key positioned in the keyway, if a key is used) and hold the heading tool at right angles to the work. Press the head of the Rivnut tightly against the sheet while slowly squeezing the handles of the heading tool together until the Rivnut starts to head over. Then release the handle and screw the stud farther into the Rivnut. This prevents stripping the threads of the Rivnut before it is properly headed. Again squeeze the handles together until the Rivnut heading is complete. Now remove the stud of the heading tool from the Rivnut by turning the crank counterclockwise.

The action of the heading tool draws the Rivnut against the anvil, causing a bulge to form in the counterbored portion of the Rivnut on



AM.381

Figure 7-42.—Hand-operated Rivnut heading and keyway cutter tools.

Table 7-5.—Drill sizes for Rivnuts.

Rivnut size	6-32	8-32	10-32
Pilot drill size	19 (0.166)	8 (0.199)	1 (0.228)
Ream drill size	12 (0.189)	2 (0.221)	1/4" (0.250)

the inaccessible side of the work. This bulge is comparable to the upset head on an ordinary solid shank rivet. The amount of squeeze required to head the Rivnut properly is best determined by practice.

When keyed Rivnuts are used, cut the keyway after the hole has been reamed. Operate the keyway cutter by inserting it in the hole and squeezing the handles. Always cut the keyway on the side of the hole away from the edge of the sheet.

Inspection

After the installation of Rivnuts, as well as other fasteners, the AMS must inspect the completed installations. The Rivnuts are inspected for the following: Manufactured head is inspected for correct installation of the Rivnut keyway in its keyway slot, insuring it is flush with the surface in which it is installed. The threaded portion of the Rivnut shank is inspected for cracks, stripped threads, and general condition. Threads that are found to be stripped may have an improperly upset head. The stripped threads would also prevent the installation of screws. When possible, in open skin areas, inspect the shank for a properly upset head.

NOTE: Rivnuts which are not to be used at the time of installation, or not used for any other reason, should be plugged with a screw designed specifically for that purpose. This will eliminate pockets, which could hold moisture and cause corrosion if left open.

Removal

Defective Rivnuts should be replaced by the same size Rivnuts whenever possible. When the hole has been enlarged by removal, substitution of the next larger size can be made. To remove a Rivnut, select a drill the same size as the original hole. Drill out the Rivnut head, using light pressure and the hollow Rivnut shank as a guide. The Rivnut shank should fall out of the hole behind the sheet, or it may be drifted out, using a pin punch.

SPECIAL RIVET AND FASTENER INSTALLATION

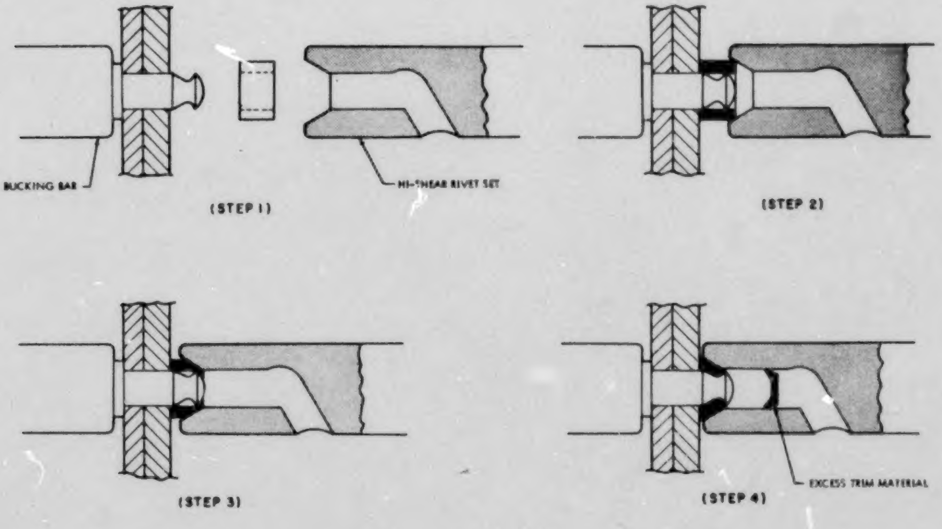
The description and use of special rivets and fasteners are covered in chapter 6. The special tools and installation and removal methods are covered in the following sections.

Installation Tools for Hi-Shear Rivets

The special tools required for use with Hi-Shear rivets differ from conventional sets only in the design of the collar swaging and trimming features and the discharge port through which excess collar material is ejected. (See fig. 7-43.) Various tools and combinations of tools are available for installing rivets in limited access areas.

Installation Procedures

Figure 7-43 illustrates four steps in the installation of the pin and collar to form the rivet. In step 1, the pin is inserted into the work. A bucking bar is placed against the head of the pin. In step 2, the collar is slipped over the grooved end of the pin. A gun or squeezer set is placed over the collar. As driving pressure is applied in step 3, the collar begins to form into the grooved end of the pin. Step 4 shows the



AM.313

Figure 7-43.—Hi-Shear rivet installation.

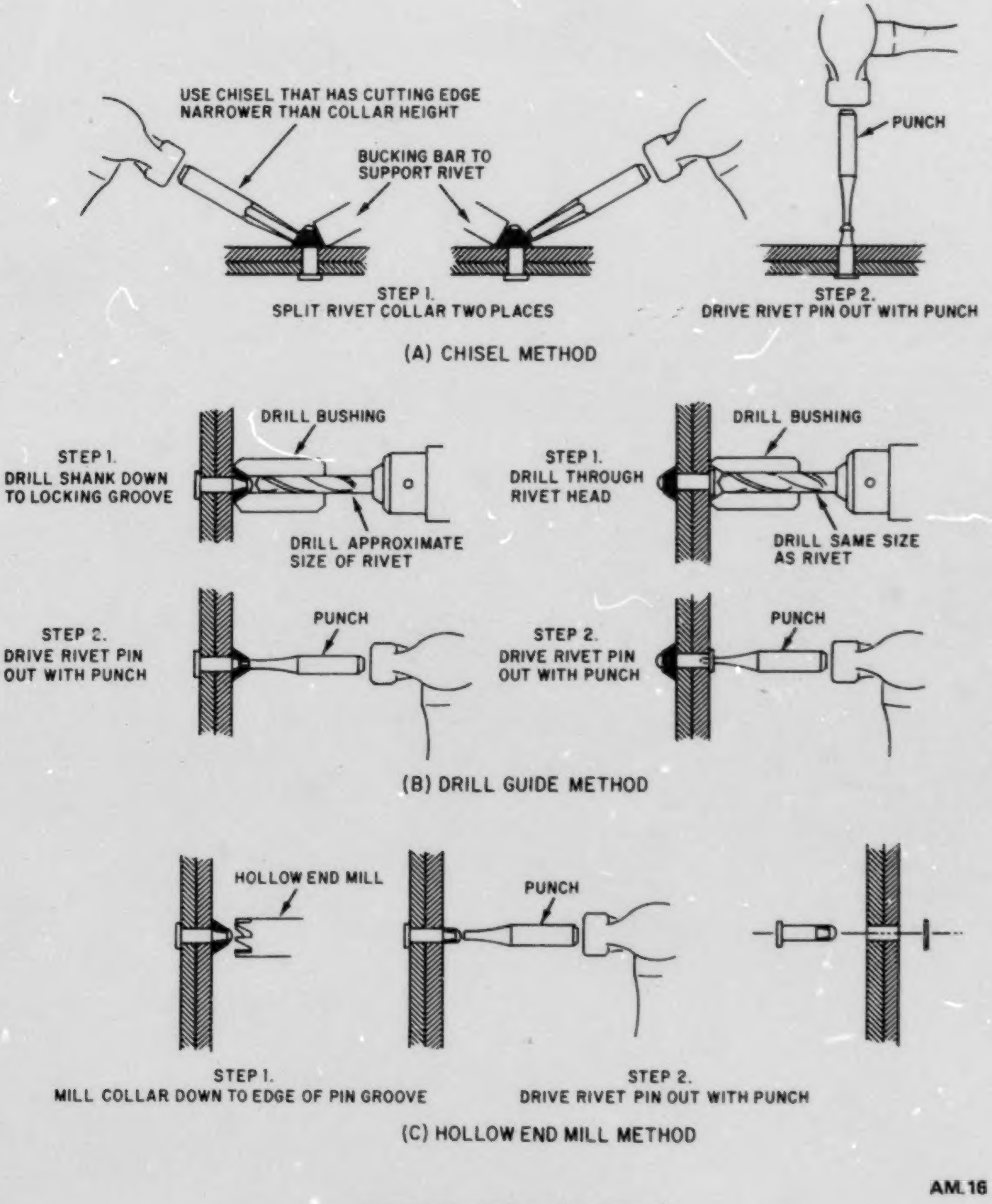

USE CHISEL THAT HAS CUTTING EDGE NARROWER THAN COLLAR HEIGHT
BUCKING BAR TO SUPPORT RIVET
PUNCH
STEP 1.
SPLIT RIVET COLLAR TWO PLACES
STEP 2.
DRIVE RIVET PIN OUT WITH PUNCH
(A) CHISEL METHOD
DRILL BUSHING
STEP 1.
DRILL SHANK DOWN TO LOCKING GROOVE
DRILL APPROXIMATE SIZE OF RIVET
DRILL BUSHING
STEP 1.
DRILL THROUGH RIVET HEAD
DRILL SAME SIZE AS RIVET
STEP 2.
DRIVE RIVET PIN OUT WITH PUNCH
PUNCH
STEP 2.
DRIVE RIVET PIN OUT WITH PUNCH
PUNCH
(B) DRILL GUIDE METHOD
HOLLOW END MILL
PUNCH
STEP 1.
MILL COLLAR DOWN TO EDGE OF PIN GROOVE
STEP 2.
DRIVE RIVET PIN OUT WITH PUNCH
(C) HOLLOW END MILL METHOD
AM.16

Figure 7-44.—Hi-Shear rivet removal.

collar formed or swaged completely into the grooved end of the pin. Excess material is trimmed off the collar automatically by the tool during driving.

Removal

Hi-Shear rivets may be removed by various methods. However, only some of these methods are recommended as the others may increase the possibility of damaging the parts. Cutting the collar off with a chisel or other sharp tool should be done only where other methods are not practical and the structure is fairly rigid. (See (A) fig. 7-44.) Special care must be taken to prevent damage to the part or to the hole. The use of a drill guide is recommended in drilling out a Hi-Shear rivet. (See (B) fig. 7-44.) The base of the guide has a conical surface which fits over the driven collar. A drill with a diameter approximately equal to the rivet diameter is then used to drill the shank end of the rivet down to the locking groove. The rivet is then driven out with a small punch. When absolutely necessary, the head of the rivet may be drilled out, but a guide should be used on protruding head rivets.

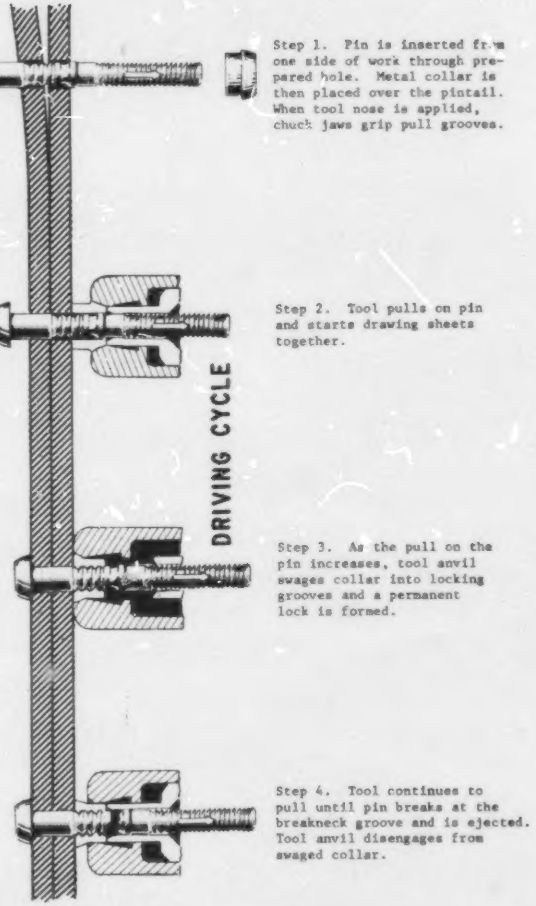
A collar removal tool, consisting of a hollow end mill, may also be used to remove the collar. (See (C) fig. 7-44.) The rotating cutter is applied to the collar until a sufficient amount of collar material has been removed to permit a sharp tap of a hammer to drive out the pin. A stop prevents the cutter teeth from contacting and damaging the work surface.

Installation Procedures for Lockbolt Fasteners

Figure 7-45 illustrates four steps in the installation of the lockbolt fastener. This fastener is installed using the CP352 pneumatic driving tool (similar to the CP350 blind rivet pull tool illustrated in figure 7-38).

Removal

Lockbolt collars may be removed by various methods. In general the procedure is the same as for removing Hi-Shear rivets. (See fig. 7-44.) Cutting the collar off with a chisel should be done only where the structure is fairly rigid. Special care must be taken to prevent damage to the structure or to the hole. The most acceptable method of removal is to cut the collar off, using a hollow end mill in a drill motor. After removal of the collar, the pin may be driven out with a punch.

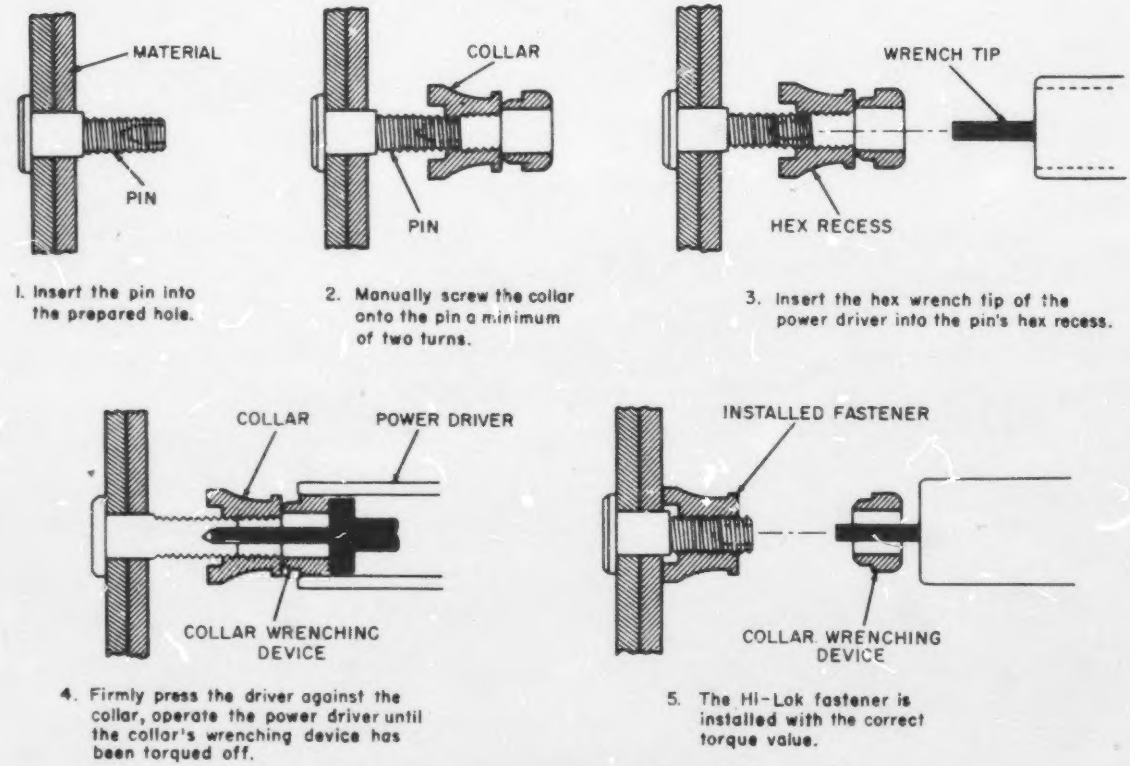

DRIVING CYCLE
Step 1. Pin is inserted from one side of work through prepared hole. Metal collar is then placed over the pintail. When tool nose is applied, chuck jaws grip pull grooves.
Step 2. Tool pulls on pin and starts drawing sheets together.
Step 3. As the pull on the pin increases, tool anvil swages collar into locking grooves and a permanent lock is formed.
Step 4. Tool continues to pull until pin breaks at the breakneck groove and is ejected. Tool anvil disengages from swaged collar.

AM.318

Figure 7-45.—Lockbolt installation.

Installation Procedures for Hi-Lok Fasteners

Hi-Lok fasteners may be installed by one person working from one side of the work, using



1. Insert the pin into the prepared hole.

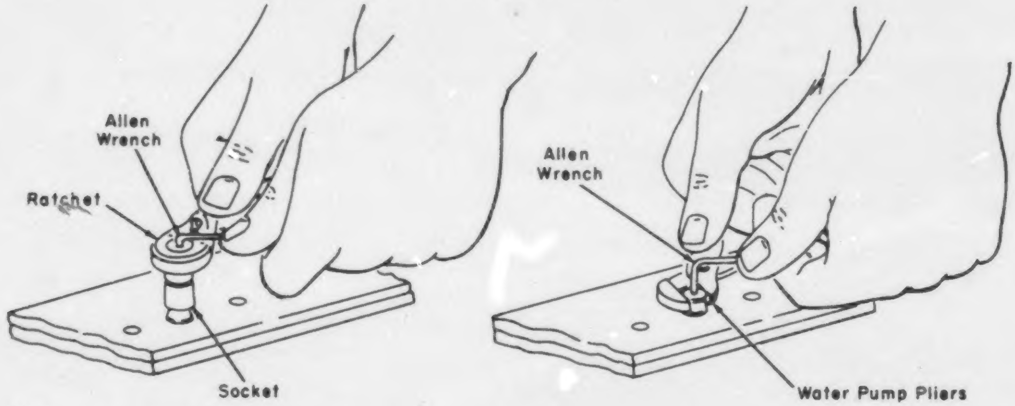
2. Manually screw the collar onto the pin a minimum of two turns.

3. Insert the hex wrench tip of the power driver into the pin's hex recess.

4. Firmly press the driver against the collar, operate the power driver until the collar's wrenching device has been torqued off.

5. The Hi-Lok fastener is installed with the correct torque value.

(A) HI-LOK INSTALLATION
(Power Tools)



(B) HI-LOK FASTENER INSTALLATION
(Hand Tools)

(C) REMOVAL OF INSTALLED HI-LOK FASTENER
(Hand Tools)

AM.17

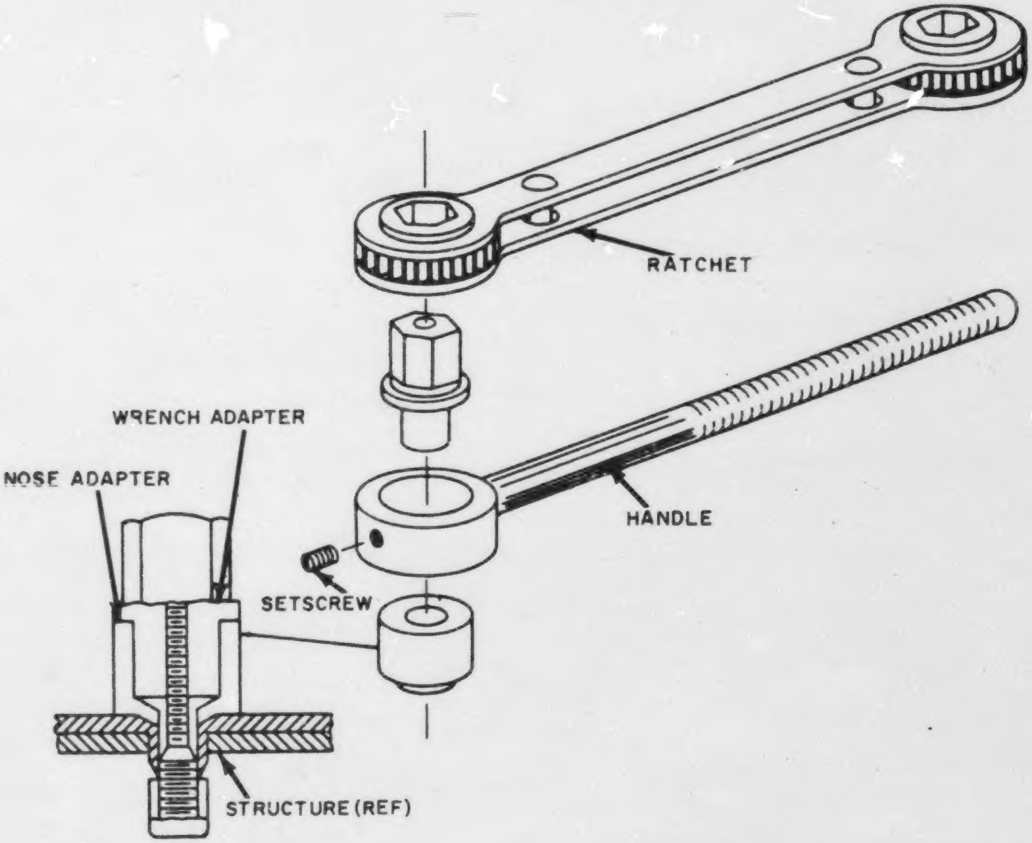
Figure 7-46.—Hi-Lok fastener installation and removal.

standard power or handtools and Hi-Lok adapter tools. Hi-Lok adapter tools can be fitted to high-speed power drivers in straight, 90-degree, offset, and extension configurations. View (A) figure 7-46 illustrates steps in the installation of Hi-Lok fasteners using power tools.

Hi-Lok fasteners may be installed using the following handtools: Allen hex key (Allen wrench) and open-end or ratchet-type wrenches. (See (B) fig. 7-46.) To install the fastener, insert the pin into the prepared hole and manually screw the collar onto the pin a minimum of two turns. Insert the proper size Allen wrench into the hex recess of the pin and, using a ratchet or open-end wrench, rotate the collar clockwise until the wrenching device of the collar has been torqued off. The fastener is installed with the correct torque value as the collars are designed to break off (torque off) at preestablished torque levels.

Removal

Hi-Lok fasteners are easily removed with standard handtools in a manner similar to removing a nut from a bolt. To remove a Hi-Lok fastener, insert an Allen wrench in the hex recess of the pin. Hold the Allen wrench firm and, using a pair of channel-lock or vise-grip pliers, rotate the collar counterclockwise until removed. (See (C) fig. 7-46.) Hi-Lok pins are reusable if no thread damage is incurred during removal. AN or NAS nuts may be substituted for Hi-Lok collars.



AM.299

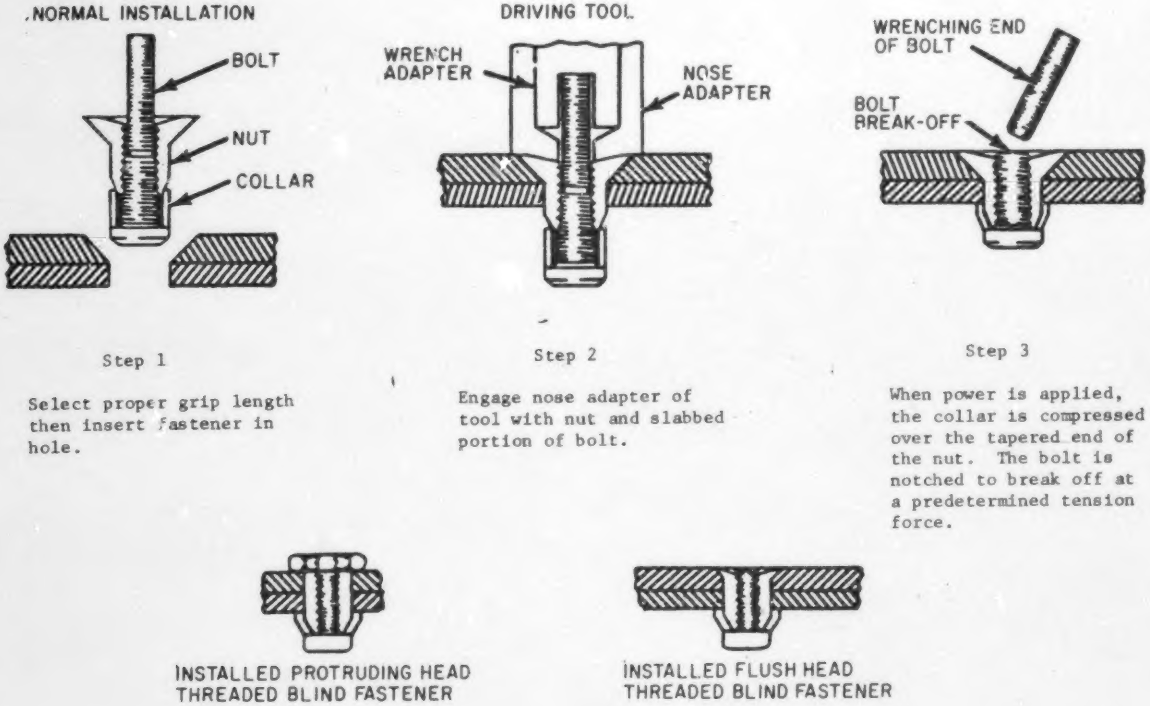
Figure 7-47.–Jo-Bolt installation tool.

Installation Tools for Jo-Bolt Fasteners

Special tools are required for the installation of Jo-Bolts. In no case shall power screwdrivers or drill motors be converted to Jo-Bolt driving tools. The handtool illustrated in figure 7-47 consists of a tool body, nose adapter, and wrench adapter which can be used for installing all sizes and types of Jo-Bolt fasteners. The nose adapter is secured in the tool body and prevents the nut portion of the Jo-Bolt from turning during installation. The wrench adapter rides free inside the nose adapter and gets its turning action from the ratchet wrench.

Installation Procedures

When installing Jo-Bolts it is important that the fastener holes and countersink diameters be the correct size for different size and type of Jo-Bolts. It is recommended that the holes be drilled undersize and then be brought up to final size for reaming. After bringing the holes up to correct size and prior to installing the Jo-Bolts, the part to be joined must be secured firmly in position. Cleco fasteners, C-clamps, or any of several varities of temporary fasteners may be used for this purpose. Figure 7-48 illustrates the installation of Jo-Bolts. Insert the correct grip length Jo-Bolt in the hole. The fastener can be pushed easily into a properly prepared hole and in no case shall it be driven forcibly into the hole. A very light tap fit is permissible in aluminum alloy parts but not in steel. Select the correct nose and wrench adapter for the fastener and secure them in the handtool body. Place the nose adapter of the driving tool over the slabbed portion of the bolt shank so that it engages the head of the Jo-Bolt. On flush head Jo-Bolts the



Step 1

Select proper grip length then insert fastener in hole.

Step 2

Engage nose adapter of tool with nut and slabbed portion of bolt.

Step 3

When power is applied, the collar is compressed over the tapered end of the nut. The bolt is notched to break off at a predetermined tension force.

AM.327

Figure 7-48.—Jo-Bolt installation.

dogs on the nose adapter shall fit into the slots of the fastener head. On the protruding head, including the millable head fasteners, the nose adapter will fit over the fastener head. Hold the tool tightly against the Jo-Bolt head and perpendicular to the surface of the work. Failure to hold the tool perpendicular may result in the stem breakoff before the Jo-Bolt is tight. Holding the handle of the tool stationary, turn the ratchet handle. As power is applied, the bolt is turned while the nut is held. The sleeve, compressed between the bolt head and tapered end of the nut, is drawn over the end of the nut. The sleeve is expanded, forming the blind head against the inner surface of the part. When the sleeve is drawn up tight, the slabbed portion of the bolt is snapped on, completing the driving operation. After driving, the end of the bolt, at the breakoff point, should be touched up with zinc chromate primer.

Removal

The procedure to be used for the removal of a Jo-Bolt will depend on whether the fastener is clamped up tight or whether it is loose. If the Jo-Bolt is clamped up tight in the hole, it can be removed by drilling just through the fastener head and then driving out the shank portion with a hammer and punch. (See (A) fig. 7-49.) If the Jo-Bolt is loose in the hole, it must be prevented from turning by using a drill bushing which has dogs to engage the head slots and a handle or other device to hold it. (See (B) fig. 7-49.) While holding the Jo-Bolt to prevent it from turning, drill the bolt portion of the fastener completely out, removing the bolt head and fastener sleeve. After the bolt head and sleeve have been removed, pick out the nut portion of the fastener. For all drilling operations on Jo-Bolts, select a drill motor that does not turn over 500 RPM.

TURNLOCK FASTENER REPAIR

A number of approved turnlock fasteners are in use on aircraft. They are used to fasten small removable inspection panels, doors, fairings, and other parts frequently removed. The AMS should be proficient in inspection and repair of turnlock fasteners. Three of the most widely used turnlock fasteners are the Camloc, Dzus, and Airloc.

CAMLOC INSTALLATION TOOLS

The following list of Camloc tools should be available to assure satisfactory Camloc installation, but does not represent the minimum tools required for any particular installation:

Pliers, No. 4P3.
Snapring tool, No. T26.
Cutters, Nos. 4-G2C and 4-GC.
Hole saws, Nos. HS-471D and HS-500.
Flaring tools, Nos. T-55-1 and T-50-1.
Dimpling tools, Nos. 4-G200M, 4-G200F, 2-S200M, and 2-S200F.

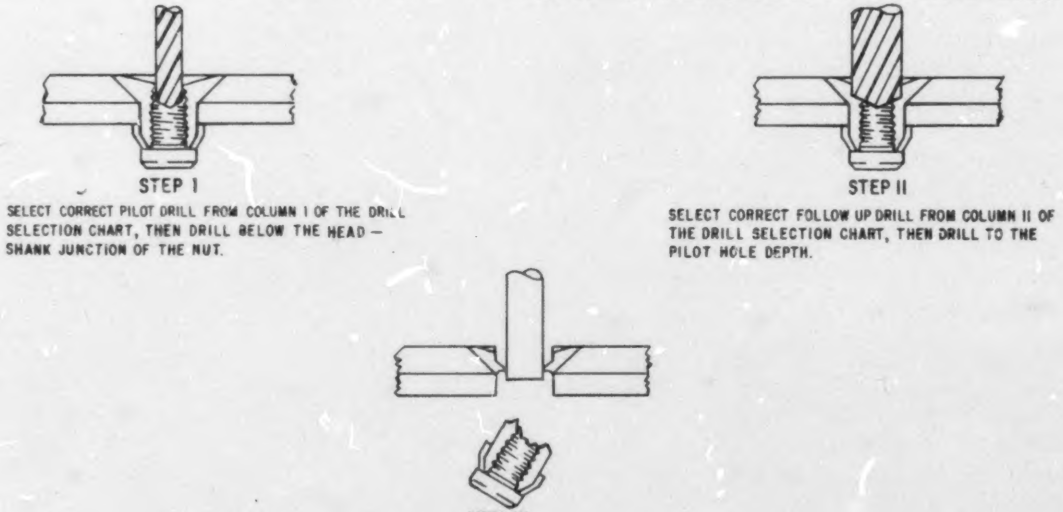
CAMLOC REPAIR PROCEDURE

Repair of Camloc fasteners includes removal of the damaged stud, grommet, or receptacle, proper preparation of the hole, and installation of the replacement part. In all cases, alignment of the stud, grommet, and receptacle must be maintained. When structural repair of the access door or access frame is necessary, all repair work should be completed before aligning receptacle holes with stud or grommet holes.

Hole preparation is dependent upon the series of fastener specified and the sheet thickness of the material to which the fastener must be attached. All holes–plain, dimpled, countersunk, or counterbored–should be predrilled undersize with the size drill (pilot hole) recommended in the Structural Repair Manual for the particular aircraft.

Remove all chips and burrs before installing fastener parts. Select proper size stud, grommet, and/or receptacle. In cases of varying sheet thickness which would cause high locking torque, the stud assembly should be replaced with one of suitable length to insure uniform low locking torque. Stud length increments of 0.030 inch allow for varying material thicknesses. The total grip length for the stud assembly includes both top and bottom sheet thicknesses. Stud selection tables will be listed in the aircraft Structural Repair Manual. Always refer to these tables for replacement sizes.

Drill Selection Chart		
Jo-Bolt	Column I	Column II
Nominal Diameter	Drill Size	Drill Size
5/32	No. 42 (0.089) (0.0935)	No. 23 (0.154) 5/32 (0.1562)
3/16	No. 35 (0.110 inch)	No. 12 (0.189 inch)
1/4	No. 24 (0.152 inch)	D (0.246 inch)
5/16	No. 17 (0.173)	M (0.295)
3/8	No. 5 (0.2055)	23/64 (0.3594)



STEP I

SELECT CORRECT PILOT DRILL FROM COLUMN I OF THE DRILL SELECTION CHART, THEN DRILL BELOW THE HEAD — SHANK JUNCTION OF THE NUT.

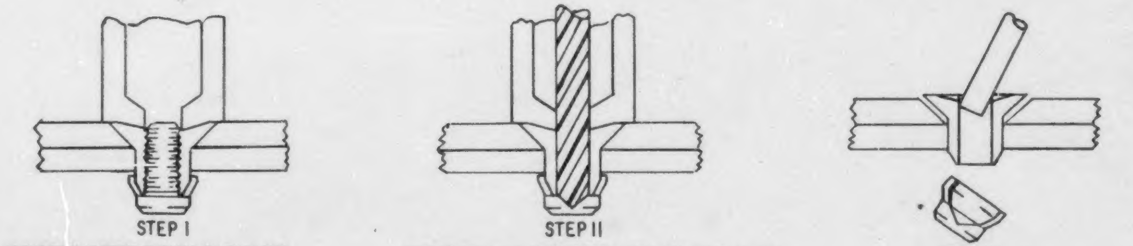
STEP II

SELECT CORRECT FOLLOW UP DRILL FROM COLUMN II OF THE DRILL SELECTION CHART, THEN DRILL TO THE PILOT HOLE DEPTH.

STEP III

USE A HAMMER AND NOMINAL SIZE PUNCH TO DRIVE OUT THE SHANK AND BLIND HEAD.

(A) TIGHT FASTENER



STEP I

PREVENT NUT FROM TURNING BY ENGAGING DRIVING TOOL NOSE ADAPTER; HOLDING THE NOSE ADAPTER WITH VISE-GRIP PLIERS.

STEP II

SELECT DRILL, IN ACCORDANCE WITH COLUMN I OF THE DRILL SELECTION CHART, THEN DRILL THROUGH THE SHANK, SEVERING THE BOLTHEAD.

STEP III

PICK THE NUT FROM THE HOLE WITH A PUNCH.

(B) LOOSE FASTENER

AM.300

Figure 7-49.—Jo-Bolt removal.

Grommet selection is determined as follows:

1. In the 4002 series, the grommet is used in combination with the stud assembly, but is dependent upon the type of hole required, the total thickness of the material, and the specified counterbore of the snapring.
2. In the 2700 series, the spring cup of the stud assembly eliminates the use of a grommet.
3. In the 40S51 series, the grommet is a nonremovable part of the stud assembly.

NOTE: Lateral movement of the grommet must be held to a minimum. Vertical movement of the grommet, when the fastener is unlocked, should be held to a minimum to prevent possible loss or fallout of the grommet.

The following repair methods apply to the 4002 series Camloc fastener.

Stud Damage

Stud assemblies 4002-1 through -15 are removed by compressing the spring with Camloc pliers and lifting out the stud. To install a new stud, compress the spring and insert the stud into the grommet. (See fig. 7-50.) When the spring is released, the stud assembly cannot fall out.

Stud assemblies -16 and longer are retained in the grommet by a split washer. No pliers are required for removal or installation of these

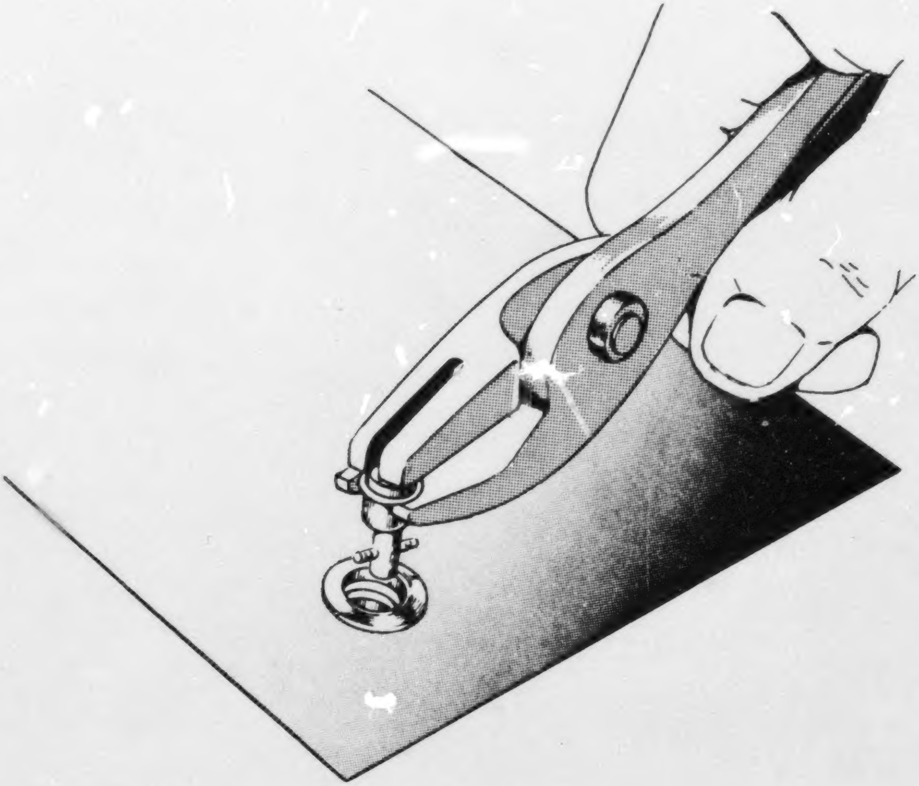
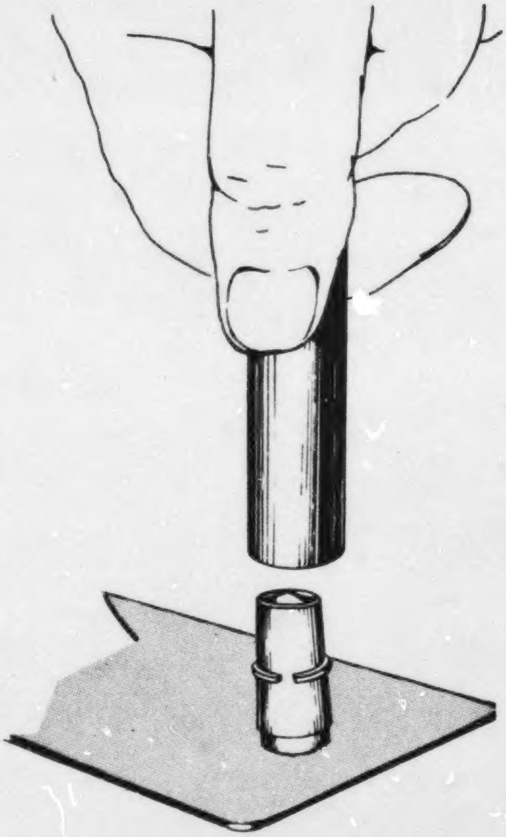

AM.382

Figure 7-50.—Installing Camloc stud.



AM.383

Figure 7-51.—Installing snapring behind shoulder of grommet.

studs. The stud is inserted in the grommet, and the split washer is placed on the stud shank between the cross pin and the spring cup. The stud cross pin should not be removed under any circumstances.

Grommet Damage

Remove the grommet by first prying off the snapring and slip the grommet out of the hole. Check for possible damage to the hole size, the dimple, or countersink, and for correct dimensions. Remove all burrs and install a new grommet identical to the original. Install a new snapring, using snapring tool T26, as shown in figure 7-51. The snapring must be fully seated behind the shoulder of the grommet.

Receptacle Damage

Remove the attaching rivets, using standard removal procedures, in replacing the damaged receptacle. The new receptacle, which should be identical to the original, is then riveted into place.

DZUS FASTENER REPAIR

Dzus fasteners are of two types, the light-duty type and the heavy-duty type. The main difference in repairing is that the heavy-duty type requires an additional operation, as the retaining grommet must also be removed and replaced. The S shaped spring is replaced if damaged or broken.

Installation

The light-duty Dzus fastener is installed in three steps. (See (A) fig. 7-52.) The hole is dimpled, using a special set of dies. The correct size of stud is then inserted in the dimpled hole. Using another set of dies, the dimpled material is then forced into the undercut of the stud, which locks the stud in place.

The heavy-duty Dzus fastener is installed in four steps. (See (B) fig. 7-52.) A hole is drilled to the proper size, and the grommet is inserted. The grommet is then set (partially flared). The correct size of fastener is then inserted through the grommet. Using a set of dies, the grommet material is flared, forcing the grommet to clinch the undercut part of the stud and the panel. This clinching action locks the stud in position.

Removal

The light-duty Dzus fastener may be removed by placing the stud over a hole in an anvil and striking it with a hammer and drift punch. After the broken stud is driven out, the hole will be too large and will be dimpled on the wrong side. This may be remedied by flattening the hole area with a hammer and redimpling with the proper size dimpling tool. Removal of the

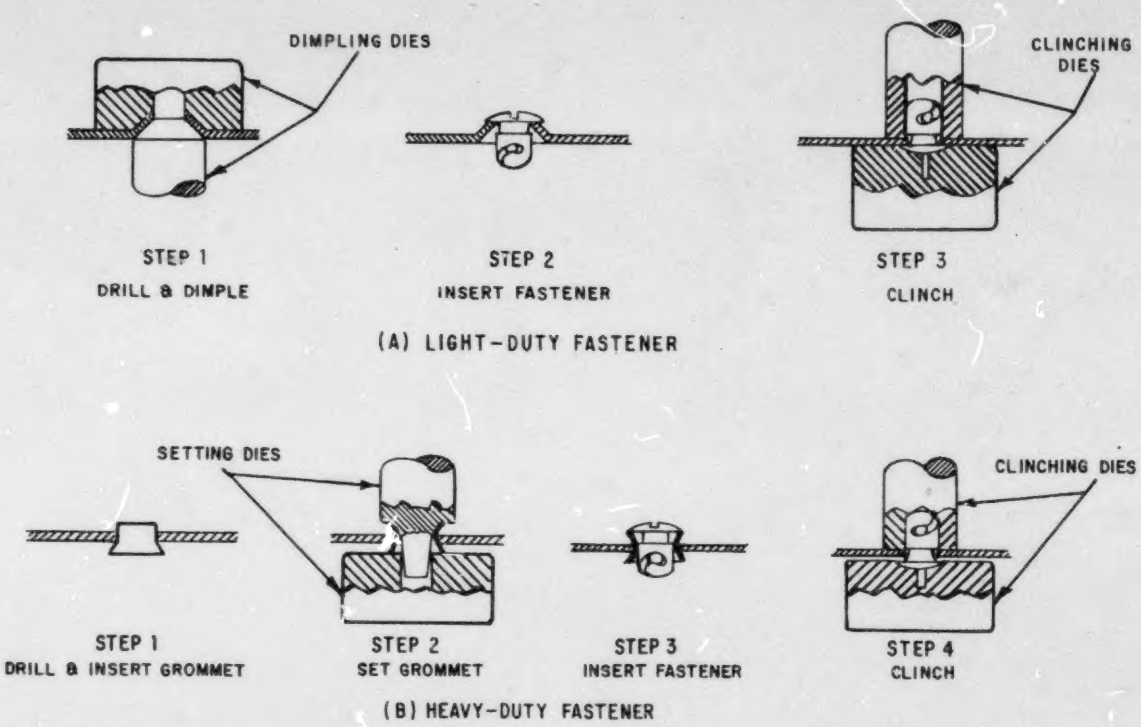


Figure 7-52.—Dzus fastener installation.

heavy-duty Dzus fastener requires a different procedure, as a grommet is used in the hole and must be cut away before the damaged stud can be removed. Insertion of a new grommet is necessary before installing a new stud.

The heavy-duty Dzus fastener may be removed by cutting away the grommet, using diagonal cutter type pliers. The old fastener is then free to fall out of the hole. Inspect the hole area for damage, and repair as necessary. The new fastener and grommet are then reinstalled in the original hole, as described earlier.

Repair of the Hole

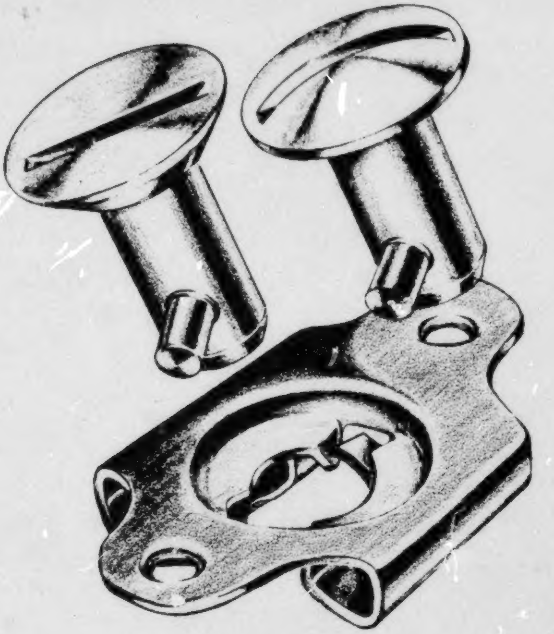
When the hole is too badly worn to permit reinstallation of the same sized heavy-duty fastener, it is recommended that a lap patch be installed over the old hole and a new hole cut in the lap patch. The new fastener is then installed in the lap patch.

Repair of a Spring

When a spring is broken or damaged, replace with an identical spring. Different spring heights are available for each fastener. There are also special springs which are used for installation in box corners and panels which would be subjected to either horizontal or vertical movements.

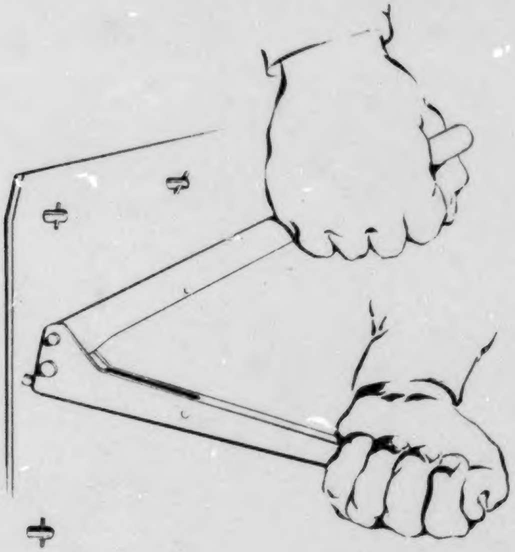
AIRLOC FASTENER REPAIR

The Airloc assembly consists of the receptacle, stud, and cross pin as seen in figure 6-10 (ch. 6). The repair of this fastener is normally made by complete replacement of the damaged parts. The stud and cross pin should never be reused due to the press fit, which is necessary for cross pin retention.



AM.385

Figure 7-53.—Airloc stud head shapes, countersunk and round.



AM.386

Figure 7-54.—Inserting cross pin, using special Airloc handtool.

Installation Procedures

The Navy normally uses Nos. 2, 5, and 7 Airloc receptacles. Each receptacle is held in place by rivets. The No. 2 receptacle is installed using 3/32-inch rivets; No. 5 uses 1/8- or 3/32-inch rivets; and the No. 7 uses 1/8-inch rivets. Receptacles with flat rivet holes may be replaced by a receptacle with countersunk holes.

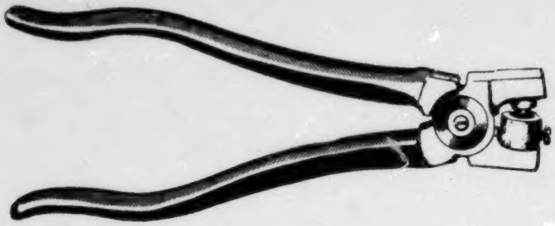
The stud normally comes in two head types, the countersunk and round head. (See fig. 7-53.) If round head studs are not available, the outer sheet may be dimpled and the countersunk head stud substituted. The head of the stud is stamped to indicate the total grip length. The length of studs is available in varying increments of ten-thousandths of an inch.

To select the proper stud, the AMS must determine the total grip length. To obtain this, add the thickness of the inner structure and outer panels, doors, gaskets, reinforcements, etc., in thousandths of an inch. Add to this, 0.010 inch to allow for wrinkling and warpage of materials. Select the nearest even 0.010 inch above the total, for the proper length of stud.

NOTE: When using a floating type receptacle, add to the preceding measurements 0.020 inch for No. 2 receptacles or 0.030 for Nos. 5 and 7 receptacles.

After determining the correct length of stud, insert the new stud into the panel or sheet. Using the special Airloc tool, press the cross pin into the stud hole, as shown in figure 7-54.

When Airloc fasteners do not fasten properly and the studs are known to be the correct length, excess misalignment is normally the cause. This condition can often be corrected by removing the panel and fastening the studs in a different sequence. Fastening the difficult studs first, or by starting in the middle of the panel and working toward each end, usually corrects this condition.



AM.387

Figure 7-55.–Hand pliers for removing cross pins.

Removal

Removal of damaged receptacles is accomplished by removing the rivets, using standard removal procedures. The stud is removed by pressing out or clipping off the cross pin. The cross pins for 1-inch and 1 3/8-inch studs are normally removed by pressing out, using special hand pliers. (See fig. 7-55.) The cross pin for 3/4-inch studs may be removed either by using the hand pliers or by clipping off the cross pin.

CHAPTER 8

AIRFRAME MAINTENANCE

This chapter is essentially a continuation of chapter 7. While chapter 7 dealt mostly with the repair of damage to the structural parts of the airframe, this chapter deals with the maintenance of nonstructural airframe components. In the area of nonstructural airframe components, the AMS is responsible for such tasks as removal, installation, and balancing of flight control surfaces; removal and installation of detachable aft fuselage sections, and replacement of glass and plastic enclosure components.

FLIGHT CONTROL SYSTEMS

Flight control systems require little routine maintenance other than inspection and lubrication. However, it is very important that these be performed as carefully and conscientiously as possible. An inoperative or malfunctioning flight control system can result in aborted flight or total loss of aircraft, cargo, and crew.

A flight control system includes all the components required to control the aircraft about each of the three axes affecting flight (ch. 4). A simple flight control system may be all mechanical; that is, operated entirely through mechanical linkage and cables from the pilot to the control surface. Other more sophisticated flight control systems may utilize electrical or hydraulic power to provide some or all of the "muscle" in the system. Still others combine some of the features of all three types of systems. The emphasis in this chapter is on mechanical systems; however, the AMS should be familiar with the hydraulic and electrical components as well. A basic knowledge of hydraulics and electricity may be attained by studying the following NavPers manuals: Fluid Power, NavPers 16193-B, and Basic Electricity, NavPers 10086-B.

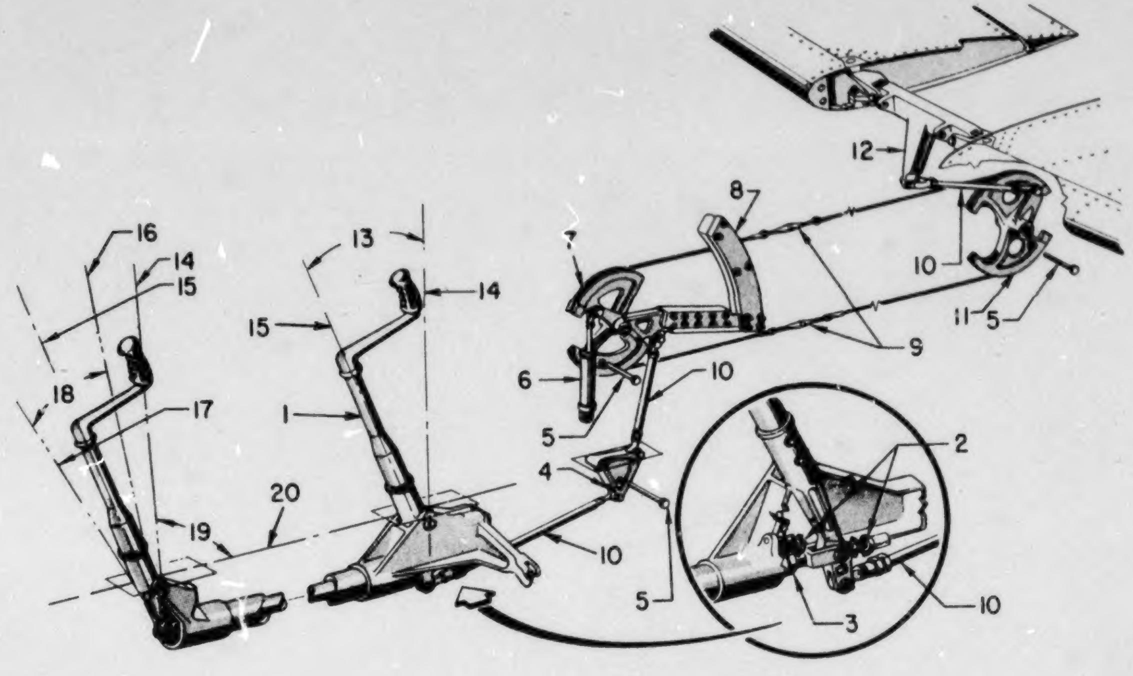
TYPICAL SYSTEM DESCRIPTION

Typical among simple, unboosted flight control systems is the primary flight control system incorporated in the T-28. The flight control surfaces (ailerons, elevators, and rudder) are actuated through a series of push-pull rods, cables, bellcranks, sectors, and idlers. Figure 8-1 schematically illustrates the elevator portion of the T-28 flight control system.

The elevators are operated by a fore-and-aft movement of the control stick. Raising the elevators causes the aircraft to climb; lowering the elevators causes it to dive or descend. The elevators are raised by pulling back on the stick, and they are lowered by pushing the stick forward.

As can be seen in figure 8-1, each control stick is mounted in such a way that it can pivot backwards and forwards on its mounting pin. The front and rear sticks are connected to each other by a push-pull rod attached to their lower ends. A second push-pull rod is attached to the lower end of the aft stick. Then, as either stick is moved longitudinally the other stick moves in the same direction and an equal distance, and the elevators are deflected proportionately. Built into the bracket supporting the rear stick are adjustable stops which limit the fore-and-aft movement of the sticks and prevent overcontrolling the elevators (see inset).

The push-pull tube (rod) that connects to the lowest point of the aft control stick extends aft to the bellcrank. Notice that the function of the



AM.432

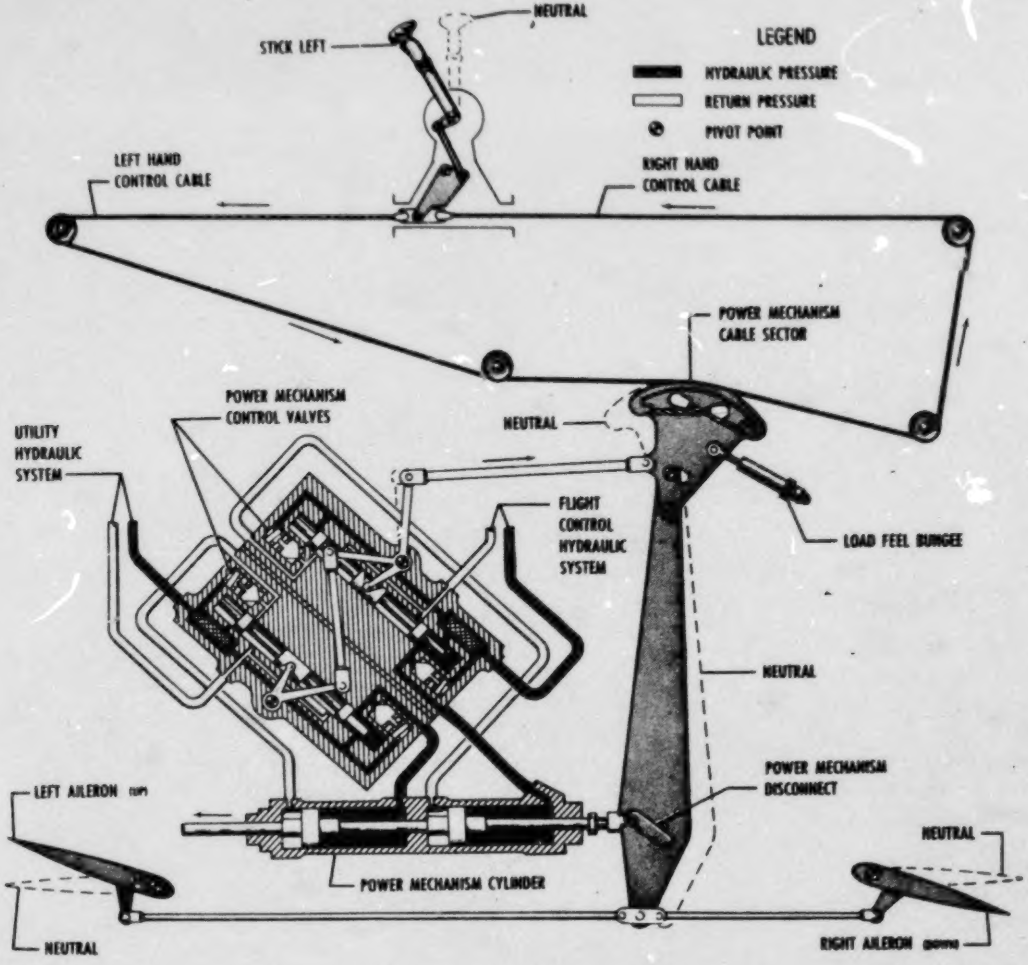
1. Aft control stick.
2. Stop bolts.
3. Push-pull tube adjustment.
4. Bellcrank.
5. Rig pins.
6. Bungee.
7. Forward sector.
8. Bobweight.
9. Turnbuckles.
10. Push-pull tubes.
11. Aft sector.
12. Elevator fitting assembly.
13. Rigging dimension.
14. Vertical reference line.
15. Centerline–stick neutral.
16. Stick throw limit–UP elevator.
17. Stick throw limit–DOWN elevator.
18. Stick throw range–elevator control.
19. Locating angle–vertical reference line.
20. Longitudinal reference line (cockpit floor).

Figure 8-1.–Typical elevator flight control system.

bellcrank is to change the direction of the push-pull action from fore-and-aft to up-and-down. The second push-pull tube connects the forward cable sector and the bellcrank and causes the sector to rotate in accordance with the stick movements.

The forward cable sector pictured in figure 8-1 incorporates a bobweight which partially compensates the system for the weight of the elevators. As the sector moves the bobweight up or down, the elevators move in the opposite direction. The elevator cables are attached to the forward edges of the sector. Also on the forward sector is an arm which connects to a centering bungee. The bungee is spring-loaded to the center position and regardless of the direction of deflection of the elevators, the bungee will assist in returning the system to neutral.

From the forward sector, the cables extend back through the aircraft to the aft cable sector. Notice in the drawing, just aft of the cable turnbuckles, a zigzag line breaking both of the cables. This is a draftsman's symbol used to indicate that the cables are really proportionately longer than is shown here but that they have been reduced in length so that the remaining essential components of the elevator control system may all be shown in the one drawing.



AM.1048

Figure 8-2.—Aileron control system.

The aft sector is essentially the same as the forward sector and acts as a slave to the forward sector. Cables from the forward sector attach to the aft edges of the aft sector. A push-pull tube from the aft sector extends to, and connects with, the elevator fitting assembly.

The elevator fitting assembly, commonly called the elevator "horn," is built onto the elevators and extends outward (usually downward) from the elevator surface at right angles to the plane of rotation and the chord line of the elevator surfaces. As the fitting assembly is moved fore or aft, the elevators are moved up or down.

The A-4 aileron control system illustrated in figure 8-2 is typical of a power boost system. This system is equipped with a power mechanism which provides hydraulic power to operate the ailerons. However, in the event of hydraulic power failure, the mechanism can be disconnected, placing the system in complete manual operation.

Operation of the system is initiated when the control stick in the cockpit is moved to the left or to the right. When the stick is moved, cables connected to the bellcrank in the control stick housing are moved to actuate the sector on the power mechanism. With the actuation of the sector, the power mechanism operates, transferring the movement to the mechanical linkage which in turn actuates the ailerons.

CONTROL SYSTEM MAINTENANCE

Control system maintenance includes inspection to discover actual and potential defects, servicing with lubricants as required, and the correction of reported malfunctions and defects.

Malfunctions which occur in control systems include frayed and loosened cables, worn and loosened bearings, unnatural tightness (binding), and broken or damaged components.

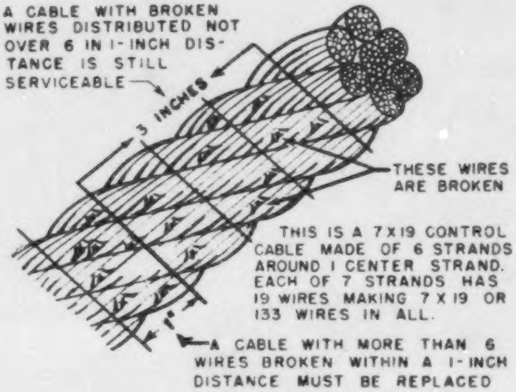
Cable Maintenance

Cable type control systems require more maintenance than rigid linkage type systems and must therefore be inspected more thoroughly. Cables must be kept clean at all times and must be inspected periodically for broken wires, corrosion, kinking, and excessive wear.

Broken wires are most apt to occur in lengths of cable which pass over pulleys or through fairleads. Tests have proved that control cables may have broken wires and still be capable of carrying their designated load. However, on certain periodic inspections, cables are checked for broken wires by passing a cloth along the length of the cable without removing the preservative. Where the cloth snags along the cable is an indication of one or more broken wires. The bare hands should never be used in checking for broken wires.

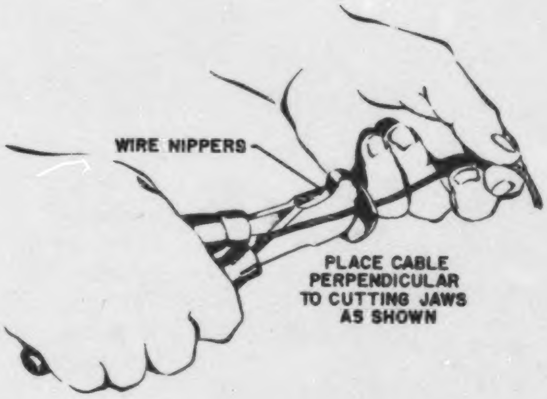
Any 7 x 19 cable that shows more than 6 broken wires in any 1-inch length, or any 7 x 7 cable that shows more than 3 broken wires in any 1 inch, must be replaced. A maximum of 3 broken wires per inch is allowable in the length of cables passing over pulleys, drums, or through fairleads. Figure 8-3 illustrates how to determine a serviceable cable.

Corrosion, kinking, and excessive wear should be given particular attention during cable inspection. If found to be kinked or badly worn, the cable should be replaced, even though the number of broken wires is less than that specified for replacement. If the surface of the cable is corroded, relieve the tension on the cable and carefully untwist the cable to visually inspect the interior. Any corrosion on the interior strands of the cable constitutes failure and the cable must be replaced. If no internal corrosion is detected, remove loose external rust and corrosion with a clean dry rag or fiber brush and apply the specified preservative compound.


A CABLE WITH BROKEN WIRES DISTRIBUTED NOT OVER 6 IN 1-INCH DISTANCE IS STILL SERVICEABLE
3 INCHES
THESE WIRES ARE BROKEN
THIS IS A 7X19 CONTROL CABLE MADE OF 6 STRANDS AROUND 1 CENTER STRAND. EACH OF 7 STRANDS HAS 19 WIRES MAKING 7 X 19 OR 133 WIRES IN ALL.
1"
A CABLE WITH MORE THAN 6 WIRES BROKEN WITHIN A 1-INCH DISTANCE MUST BE REPLACED

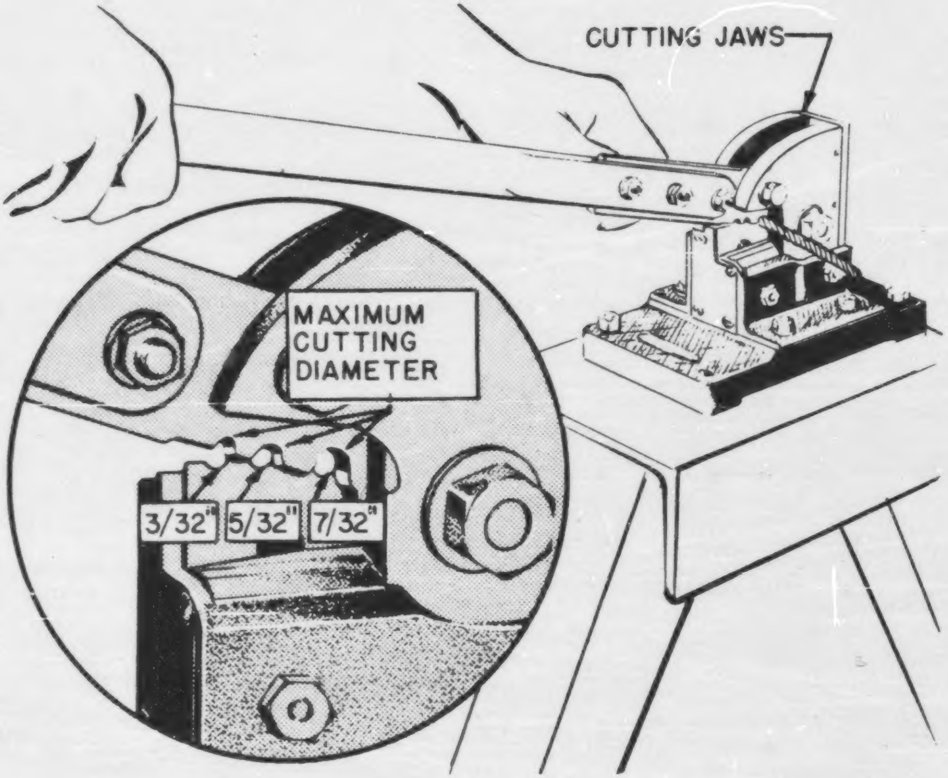
AM.433

Figure 8-3.—Determining serviceable cable.


WIRE NIPPERS
PLACE CABLE PERPENDICULAR TO CUTTING JAWS AS SHOWN

AM.434

Figure 8-4.—Cutting small cable with wire nippers.



AM.435

Figure 8-5.—Cable cutting machine.

NOTE: Do not use metal wool or solvents to clean installed cable as use of metal wool will embed tiny dissimilar metal particles, thus creating further corrosion problems; and the use of solvents will remove the internal cable lubricant, allowing the cable strands to abrade and further corrode.

When a cable is found to be unserviceable and a spare cable is not available, an exact duplicate of the damaged cable may be prepared. This will involve cutting a length of cable to the proper length, attaching the necessary end fittings, and testing the assembly.

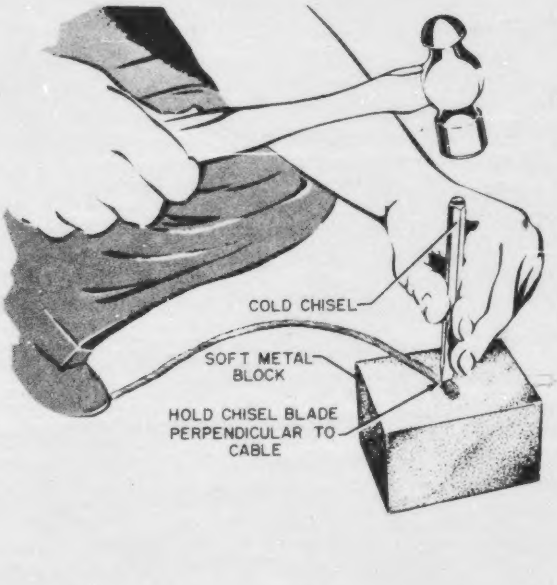
In determining the proper length to which the new cable will be cut, it is first necessary to determine the overall length of the finished cable assembly. This may be accomplished by measuring the old cable assembly, or from measurements provided in the Maintenance Instructions Manual for the aircraft concerned.

Cutting of cables may be accomplished by any convenient method except an oxyacetylene cutting torch. The method of cutting usually depends upon the tools and machines available. If a cable tends to unravel, the ends may be sweat-soldered, or wrapped with a strip of tape prior to cutting.

Small diameter cable may be cut satisfactorily with a pair of heavy-duty diagonal cutters, side cutters, or a pair of wire nippers similar to those shown in figure 8-4. Best results are obtained if the cutting jaws are held perpendicular to the cable during the cutting operation. Cables up to 3/32 inch in diameter may be cut in one operation by this method. Larger cables may require two or more cuts. When cutting large diameter cables in this manner, use the end of the cutting blade and cut only a few strands at a time.

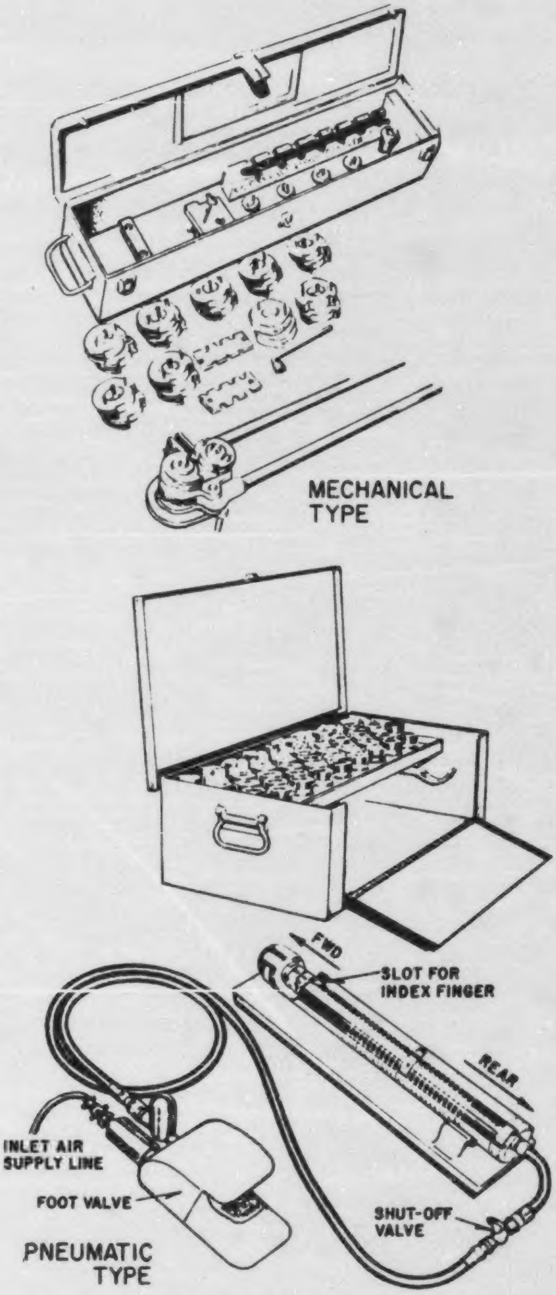
The most satisfactory method of cutting cables is with a cable-cutting machine having special jaws to accommodate various sizes of cable. (See fig. 8-5.) To use this machine, position the cable in the proper diameter groove and hold the cable firmly within 2 inches of the cutting blades. Hold the cable at right angles to the cutting blades and pull the operating handle down sharply.

A cold chisel used in conjunction with a soft metal block may also be used for cutting cables. This method should be used only as a last resort because of the way the cable ends will be frayed. Figure 8-6 illustrates this method of cutting a cable. The chisel should be held straight up, with the cutting blade at right angles to the cable. Using a heavy hammer, strike the chisel with a


COLD CHISEL
SOFT METAL BLOCK
HOLD CHISEL BLADE PERPENDICULAR TO CABLE

AM.436

Figure 8-6.—Cutting cable with a cold chisel.



AM.437

Figure 8-7.—Hand-swaging tools—mechanical and pneumatic.

hard, sharp blow in order to get a clean, square cut.

After the cable is cut, the next step in making up an aircraft cable is attachment of the terminals. Most terminal fittings are SWAGED onto the ends of control system cables. Swaging is essentially a squeezing process in which the cable is inserted into the barrel of the terminal, then by great pressure applied by dies in a swaging machine, the barrel of the terminal is compressed or shrunk in diameter so that it clasps tightly around the cable, and the metal of the inside walls of the barrel is molded and cold flowed by force into the crevises of the cable. Figure 8-7 illustrates two types of hand-swaging tools. The one in the upper part of the illustration is mechanically operated, while the lower one is pneumatically operated.

When preparing to swage a terminal, cut the cable to the required length, allowing for the elongation (increase in length due to stretching) of the fitting which will occur during the swaging process. The amount of elongation will vary with the type and size fitting used. Therefore, the elongation must be taken into account whenever making up any cable. Tables are furnished in the publication NavAir 01-1A-8, Aircraft Structural Hardware, or superseding publication, which provides elongation data for all types and sizes of fittings.

Make sure that the cable end is cut square and clean and that all strands remain in a compact group as shown in figure 8-8. Place a drop or two of light lubricating oil on the cable end, then insert the end into the terminal to a depth of about 1 inch. Bend the cable toward the terminal, straighten it back to the normal position, then push the cable all the way into the terminal barrel. This bending process puts a kink in the cable end, which provides enough friction to hold the terminal in place until the swaging operation is completed. It also tends to separate and spread the strands inside the terminal barrel, thus reducing the strains caused by swaging.

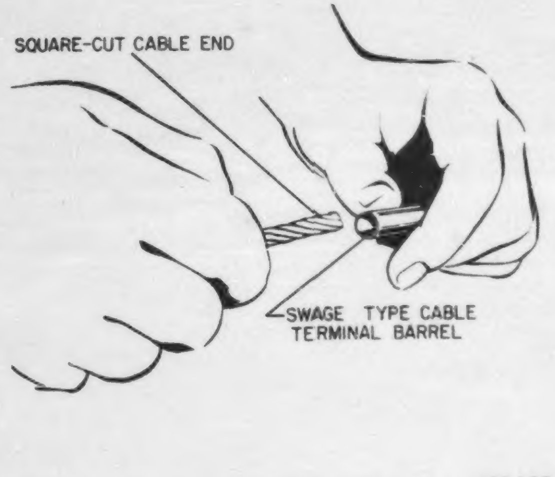

SQUARE-CUT CABLE END
SWAGE TYPE CABLE TERMINAL BARREL
AM.438

Figure 8-8.—Inserting cable in swage-type terminal.

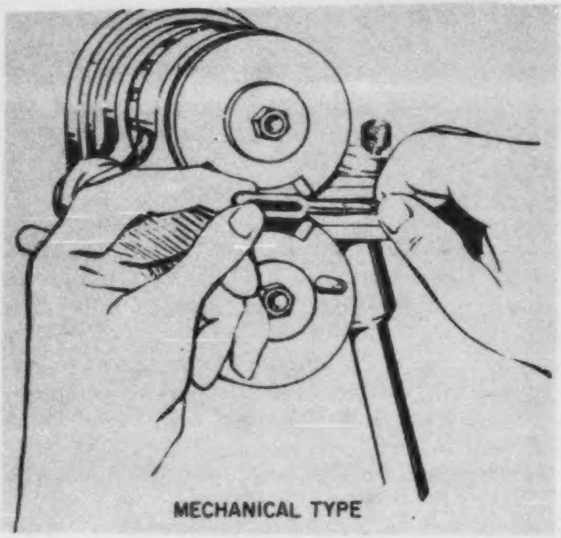
Both of the hand-swaging tools shown in figure 8-7 are widely used by naval aircraft maintenance activities. The procedure for using both types is described in the following paragraphs.

When operating the mechanical type, the AMS places the proper size pair of dies on the swaging tool. The terminal is then located in the jaws of the tool as shown in figure 8-9, and the swaging operation is performed. As the dies rotate in such a manner as to pull the terminal from right to left, the dies compress the terminal barrel onto the cable and swaging occurs. Rotation of the dies is accomplished by opening and closing the handles in the manner of a pair of scissors.

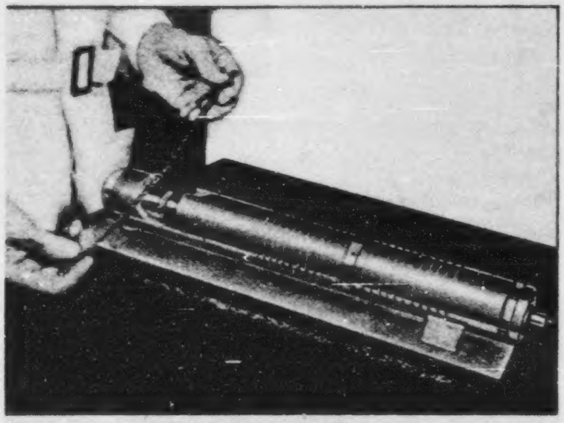
After completion of swaging and removal of the fitting from the swaging tool, measure the outside diameter of the shank with a micrometer or with the gage furnished with the swaging outfit to determine whether or not the terminal has been swaged sufficiently. This may be determined by checking the measurement with the applicable cable terminal table in NavAir 01-1A-8.

The pneumatic swaging tool shown in figure 8-7 is a lightweight portable unit designed to precision swage the metal of a terminal into the interstices (crevices) of the cable strands. The swager may be mounted on a base plate and used on a bench, or it can be taken to the job. When the swaging tool is taken to the location of the job, it may be held in the hand at the balance point or cradled in the arm while using.

The pneumatic swaging kit has several different sizes and types of dies used for swaging ball and sleeve type terminals and for cutting



MECHANICAL TYPE



PNEUMATIC TYPE

AM.439

Figure 8-9.–Locating the terminal in the swaging tools.

and trimming cable. Like the mechanical swaging tool, the dies come in matched sets, and must be used together. The dies are installed by inserting either die through the yoke opening, into the die cavity with the keyway down and the shank facing to the rear of the swager. Slide the first die back in order to clear the opening for the insertion of the mating die. The second die is inserted with the shank facing forward.

The following step-by-step procedure is recommended for setting up the pneumatic swaging tool:

1. Connect the air supply to the foot valve. For efficient operation use an inlet air line with at least 3/8 inch inside diameter and 90 pounds minimum line pressure.
2. Connect the swager air line to the foot valve.
3. Clean the dies, remove any steel particles which may have adhered to the die cavity, and apply a light film of oil to the entire die.
4. Insert the dies in the swaging tool as previously described.

CAUTION: Do not insert or remove dies until the air supply which is connected to the swager is shut off.

With the pneumatic tool set up for use, the following steps should be followed while swaging terminals to cables.

1. Position the terminal on the cable, using the old cable as a pattern, or follow the instructions given in the applicable technical directives. When using a ball type terminal, a minimum 1 1/2 inches of cable must extend beyond the ball to allow room for holding and turning the terminal during swaging. The excess is trimmed, if necessary, after the swaging operation. When using MS 20667 terminals, 1/4 inch of cable must extend through the terminal. On all other terminals, the cable is bottomed (inserted all of the way into the terminal).
2. Each terminal is cleaned, using a suitable solvent, then coated with a light oil.
3. With the terminals positioned in the cavity of the forward die, slide the rear die to its forward position using the slot provided in the yoke for the index finger.

NOTE: To prevent damage to terminal or cable during the swaging cycle, maintain light pressure on the cable towards the front of the swager. This holds the terminal and cable firmly in the forward die cavity.

4. Depress the foot valve firmly and rotate the cable back-and-forth in 180-degree arcs or complete revolutions. The length of time the foot valve is held depends upon the type and size of fitting being swaged. This time can be found by referring to the chart supplied with the

pneumatic swaging tool. If the terminal will not rotate, stop swaging immediately, rotate the terminal 90 degrees, and start swaging again.

5. Release the foot pedal to stop swaging, and remove the terminal from the swaging tool for inspection. If the diameter is oversize or the terminal surface is too rough, repeat the operation.

If swaged terminals are to be used on both ends of the cable, recheck the overall length of the cable and trim, if necessary, prior to installing the second terminal. Make certain that all additional fittings and accessories, such as cable stops and fairleads, are slipped onto the cable in the proper sequence. The other terminal may then be swaged, using the same procedure as that used for the first one.

All newly fabricated cables should be tested for proper strength before they are installed in aircraft. The test consists of applying a specified tension load on the cable for a specified number of minutes. The proof loads for testing various size cables are given in tables contained in NavAir 01-1A-8, or subsequent publications. Proof loading will result in a certain amount of permanent stretch imparted to the cable. This stretch must be taken into account when fabricating cable assemblies. Cables which are made up slightly long may be entirely too long after proof loading.

Replacing of cables in the aircraft, especially those routed through inaccessible spaces, can be difficult. One method used is to secure a snaking line to the cable to be replaced, remove the pulleys from the brackets, and pull out the old cable, pulling the snaking line into the cable system run at the same time. Attach the new cable assembly to the snaking line and pull the snaking line out to pull the new assembly into place. Replace the pulleys and attach the new cable in the system.

Push-Pull Linkage Maintenance

Push-pull tube linkage must be inspected closely for dents and cracks and for bent lengths of tubing. Damaged tubes may have to be replaced. End fittings are checked for damage and for wear and security of attachment. Worn or loose fittings must be replaced.

When replacing a damaged push-pull tube, the correct length of the new tube is obtained by loosening the checknut and turning the end fitting in or out, as necessary. When the push-pull tube has been adjusted to its correct length, the checknut must be tightened against the shoulder of the end fitting. Normally, only one end of a push-pull rod is adjustable. The adjustable end has a hole (witness hole) drilled in the rod, located at the maximum distance the base of the end fitting is allowed to be extended. If the threads of the end fitting can be seen through this hole, the end fitting is within safe limits.

When attaching push-pull tubes with ball bearing end fittings, the attaching bolt and nut must tightly clamp the inner race of the bearing to the bellcrank, idler arm, or other supporting structure. A nut and bolt only finger tight does not utilize the bearing for the purpose it was intended. Therefore, nuts should be tightened to the torque values listed in the aircraft Maintenance Instructions Manual.

After installing a new push-pull tube in a flight control system, the control surface must be checked for correct travel. Procedures for accomplishing this are described later in this chapter. If travel is incorrect, the length of the push-pull tube must be readjusted.

Troubleshooting

When the cause and remedy for a reported malfunction in a control system are not immediately obvious to the AMS it may be necessary to troubleshoot the system. Most aircraft Maintenance Instructions Manuals provide troubleshooting charts which list some of the more common malfunctions likely to occur in the system. Each discrepancy is accompanied by one or more probable causes and a remedy is prescribed for each cause. The troubleshooting charts are organized in a definite sequence under each possible trouble, according to the probability of failure and ease of investigation. In order to obtain maximum value from these charts, they should be used systematically in accordance with the aircraft manufacturer's recommendations. A portion of the troubleshooting chart for the control system illustrated in figure 8-1 is shown in table 8-1.

Table 8-1.–Troubleshooting flight control system.

Trouble	Probable cause	Remedy
Cockpit controls hard to move.	Control system not rigged correctly.	Rerig control system.
	Control cable tension too high.	Check tension with tensiometer.
	Equipment or structure interfering with movement of control system.	Check routing of linkages and cables, correct as necessary.
	Control cable fouled on equipment.	Check vicinity of turnbuckles.
	Control cables incorrectly routed.	Reroute control cables.
	Pulley out of alignment.	Straighten or replace pulley bracket.
	Defective or dry bearing in the system.	Clean and lubricate bearing or replace if damaged.
	Defective bungee in system.	Adjust bungee. Replace if necessary.
	Sectors torqued too high.	Isolate sector and torque to proper value or replace if defective.
Cockpit controls will not move with the surface controls disconnected.	Rig pin left in system during rigging procedure.	Remove rig pin.
	Bungee jammed.	Remove and repair, or replace.
	Foreign object jammed into system.	Remove foreign object and inspect system for damage.
	Quadrant bolt torque too high.	Torque bolt to specified torque as per Maintenance Instructions Manual.
Control surfaces will not move.	Attaching bolts overtorqued.	Torque correctly.
	Movable surface striking or binding on fixed surface. Hinge pin bent or misaligned.	Replace or repair movable surface as required. Replace or align.

Since most present day aircraft incorporate some form of electrical control and/or hydraulic boost in their flight control systems, maintenance of these systems must include the related electrical circuits and hydraulic systems in many instances. Although an AE or AMH is generally called upon to locate and correct electrical or hydraulic troubles, respectively, the AMS should be able to check circuits for loose connections, perform continuity checks if necessary, and perform minor troubleshooting of the hydraulic system. A knowledge of electrical and hydraulic symbols and the ability to read electrical circuit diagrams and hydraulic system schematics are necessary; therefore, the AMS should study the training manuals Basic Electricity and Fluid Power.

Loose electrical connectors are located by checking all those in the circuit. A connector that can be turned by hand is loose and should be tightened handtight.

A continuity check is simply a matter of determining whether or not the circuit to the applicable unit is complete. The check for continuity may be made with a test lamp, which can be drawn from supply.

To perform an electrical continuity check, the connector at the electrically controlled unit is first disconnected. Then, with all necessary switches and circuit breakers closed, the test lamp is connected into the circuit at the electrical connector. The lamp thus indicates whether or not the circuit is complete.

Continuity checks may also be made with the use of a multimeter. A multimeter is an instrument used for measuring resistance, voltage, or amperage. Using this instrument is primarily the responsibility of the AE; however, the AMS may learn to use it by referring to Basic Electricity, NavPers 10086-B, Chapter 15. Remember, certain portions of this training manual are recommended supplemental reading for all AMS personnel.

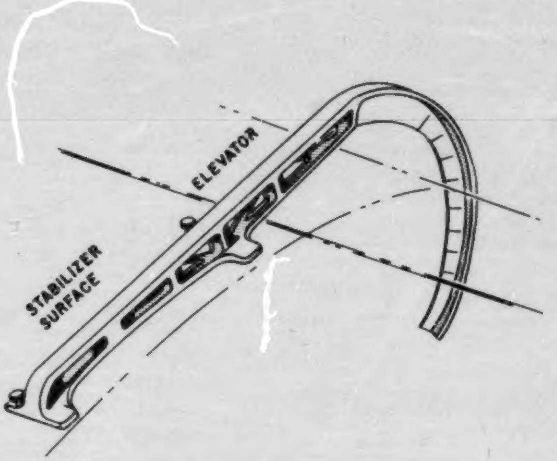
Satisfactory background information on hydraulic theory may be acquired by referring to the training manual, Fluid Power, NavPers 16193 (Series).

Rigging and Adjustment

The purpose of rigging and adjusting a flight control system is to insure neutral alignment of all connecting components and to regulate and limit the surface deflection in both directions. In the elevator system illustrated in figure 8-1, rigging begins at the aft sector.

The aircraft manufacturer has determined the position of the aft sector when it is in the neutral position. He has furnished a rig pin hole in the sector and a mating hole in the adjoining structure. (See (5) in fig. 8-1 at aft sector.) With the rig pin inserted in the aft sector and in the aircraft structure the sector is held firmly in the neutral position. With the sector in this position, the push-pull tube connecting the sector with the elevator fitting assembly is adjusted to position the elevators to the neutral (streamlined) position. The neutral position is determined by use of an elevator rigging fixture illustrated in figure 8-10. The curved section of the rigging fixture is graduated in degrees on either side of the neutral (zero degree) position which is about midway of the curved part of the rigging fixture.

The rigging fixture is fastened securely to the aircraft at indicated points of attachment. When properly mounted, the index marks (graduations) on the curved section align with the elevators and indicate the position, in degrees, of



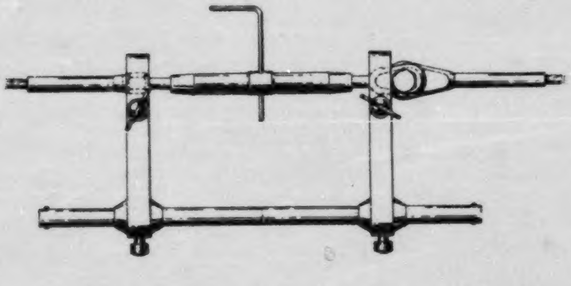
AM.390

Figure 8-10.—Elevator rigging fixture.

the elevators at any time. If, with the aft sector rig pin in place, the elevators are not in neutral; for example, 5 degrees above the neutral mark, lengthening the push-pull rod end will push the elevator fitting assembly forward and thereby lower the elevators. If the elevators are too low, then shortening the rod will bring them up as required.

The next step in rigging and adjusting is the adjusting and tightening of the pair of cables in the system. This is accomplished by tightening the turnbuckles on each cable evenly until the required tension is obtained. During cable tightening the rig pin is retained in the aft sector, leaving the forward sector free to turn. Therefore, when the necessary tension is recorded on one cable, that is also the tension on the other cable. To insure that the cables were tightened evenly, check the forward sector rig pin hole to see if the rig pin can be inserted through the sector and into the structure. If this is not possible, then the cables must be adjusted by loosening one and tightening the other the same amount. This will maintain the correct tension on the cables and at the same time rotate the forward sector to the neutral position. The cable section is properly rigged when it is possible to insert and remove the forward sector rig pin easily with the aft sector pin installed and the cables tightened to the prescribed tension. Figure 8-11 illustrates a tool for holding the terminals on cable ends to prevent their rotation while adjusting the turnbuckle barrel.

When all adjusting and rigging on the cables is completed, safety the turnbuckles as necessary. As mentioned in chapter 6, only two methods of safetying turnbuckles have been adopted as standard procedures by the armed services—the clip-locking (preferred) method and the wire-wrapping method.



AM.391

Figure 8-11.—Turnbuckle rigging clamp.

CLIP-LOCKING TURNBUCKLES.—The clip-locking method of safetying uses an NAS lock clip. To safety the turnbuckle, align the slot in the barrel with the slot in the cable terminal. Hold the lock clip between the thumb and fore-finger at the end loop. Insert the straight end of the clip into the aperture formed by the aligned slots. Bring the hook end of the lock clip over the hole in the center of the turnbuckle barrel and seat the hook loop into the hole. Application of pressure to the hook shoulder at the hole will engage the hook lip in the turnbuckle barrel and complete the safety locking of one end. The above steps are then repeated on the opposite end of the turnbuckle barrel. Both locking clips may be inserted in the same turnbuckle barrel hole or they may be inserted in opposite holes. (See fig. 6-40 in chapter 6.)

Lock clips must be examined after assembly for proper engagement of the hook lip in the turnbuckle barrel hole by the application of slight pressure in the disengaging direction. Lock clips must not be reused, as removal of the clips from the installed position will severely damage them.

WIRE-WRAPPING OF TURNBUCKLES.—First, two safety wires are passed through the hole in the center of the turnbuckle barrel, and the ends of the wires are bent 90 degrees toward the ends of the turnbuckle, as shown in figure 6-40.

Next, the ends of the wires are passed through the holes in the turnbuckle eye or between the jaws of the turnbuckle fork, as applicable. The wires are then bent toward the center of the turnbuckle and each one wrapped four times around the shank, securing the wires in place.

When a swaged turnbuckle terminal is being safetied, one wire must be passed through the hole provided for this purpose in the terminal. It is then looped over the free end of the other wire and both ends wrapped around the shank, as shown in figure 6-40.

RIGGING AND ADJUSTING RIGID CONTROLS.—The push-pull tube connecting the forward sector and the bellcrank is adjusted to the correct length by installing a rig pin in the bellcrank and turning the rod adjustable eye in or out until the rod can be installed between the sector and bellcrank without binding. At this point three rig pins are in place and should remain in place until the control sticks are rigged to neutral.

When positioning the control sticks to neutral the rear stick must be adjusted first as we are working forward from the elevator surface. The push-pull tube connecting the bottom of the rear stick with the bellcrank must be adjusted until the stick centerline (15, fig. 8-1) is the prescribed number of degrees forward of a vertical reference line (14). The vertical reference line is a position that the centerline of the control stick would attain at a 90-degree angle (19) to the cockpit floor (20), as determined by a level protractor.

Adjust the length of the push-pull tube between the control sticks to position the front control stick to an angle identical to that of the aft control stick, and remove all three rig pins. This completes the rigging and adjusting of the control system to neutral. All that remains is to adjust the stops that limit the fore and aft travel of the control sticks and rig and adjust the bungee that holds the system in the neutral position.

The stop bolts (2, fig. 8-1) are located, one each, in front and behind the aft control stick. They are installed so that the stick contacts the stop bolts at the extreme limits of its travel. The maximum travel of the elevators in each direction is determined by the manufacturer and is controlled by the stop bolts. With the rigging fixture still in place, move the control stick all the way forward and adjust the stop until the elevator DOWN throw conforms to the instructions in the applicable Maintenance Instructions Manual. Pull the stick all the way aft and adjust the aft stop bolt to obtain the correct elevator UP throw. The stop bolts are safety wired in place after this adjustment.

The last item to be adjusted in this control system is the centering bungee. Connect the bungee and adjust its rod end so that with the stick against the stop bolt in the full down elevator position, the bungee is a minimum of 1/32 inch from bottoming. After this adjustment the elevators should be held in neutral (plus or minus the prescribed number of degrees) by bungee action. If the elevators are too high, shorten the bungee rod end. If they are too low, lengthen the bungee. With the bungee properly adjusted, tighten the bungee rod end locknut and safety it as required.

Removal and Installation

It is sometimes necessary to remove control surfaces from aircraft for the purpose of repair or replacement. The instructions presented in the following paragraphs are general instructions, applicable to several types of aircraft. For specific instructions and precautions, always consult the applicable Maintenance Instructions Manual before removing a control surface from any aircraft.

REMOVAL.—Removal of a control surface should not be attempted until the aircraft is placed in a hangar or other area protecting it from the wind. Before any control surface is removed from the aircraft, it should be tagged with the bureau number of the aircraft and the location of the control surface on the aircraft.

The first step is to remove the necessary access opening covers and fairings. To prevent the loss of these inspection plates and fairings, they should be left attached to the aircraft by one screw or by a piece of safety wire. The other screws should be put in a container to prevent them from being lost.

Disconnect bonding wires, electrical connectors, and control linkage. Before disconnecting cable linkage, the tension should be relieved at the most convenient turnbuckle. Next, support the entire control surface, either manually or with mechanical supports, in such a manner as to remove all the load from the hinges. Remove the hinge bolts, using a mallet and brass drift pin where necessary. The control surface should be supported and all the hinges kept in alignment until the last hinge bolt has been removed. On long control surfaces it may be necessary to replace the hinge bolts with drift pins to keep the hinges aligned while removing the remaining hinge bolts.

Secondary and auxiliary control surfaces are sometimes attached with piano wire hinges. Removal of the piano wire can be accomplished by cutting off the bent ends, securing one end of the wire in the chuck of a hand drill, and rotating the wire with the drill while withdrawing it. Excessive spinning will have a wearing effect on the hinge material and should be avoided. The reuse of piano hinge wire is not considered safe, therefore, any wire removed should be discarded.

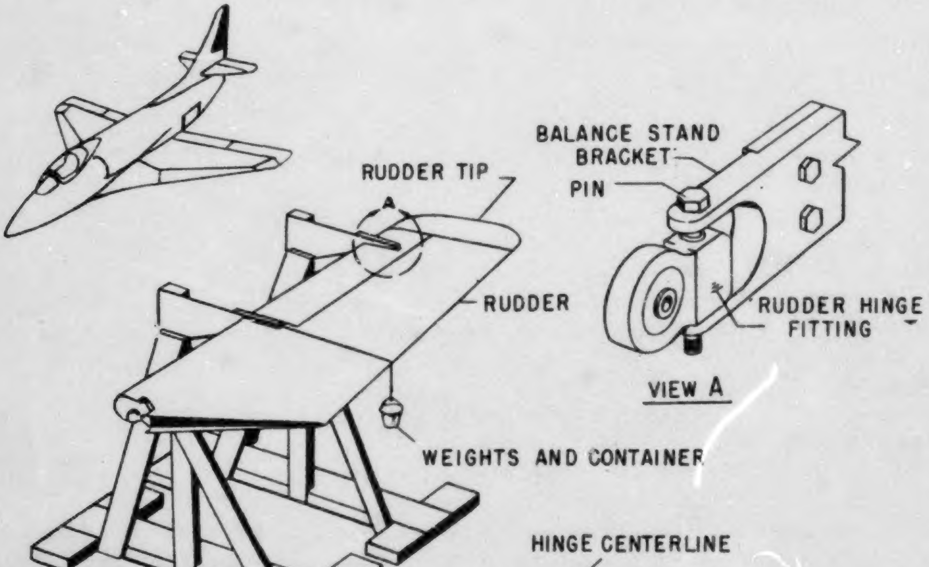
After all the hinges are disconnected, remove the control surface from the aircraft, supporting it carefully to prevent damage to the hinge brackets and adjoining surfaces. Replace the hinge bolts in the hinges to prevent them from being lost or damaged.

INSTALLATION.–Before installing a control surface, check the identification tag to determine the location on the aircraft. Place the surface in position carefully, being sure that all the hinge holes are properly aligned. Drift pins may be used to align the holes. With the control surface correctly supported, install the hinge bolts. In the case of a secondary or auxiliary surface attached by piano hinge wire, a new wire should be used.

After a control surface is installed, the control linkage is then connected and the rigging of the system checked.

Balancing of Flight Control Surfaces

All flight control surfaces are balanced at the time of manufacture by the addition of counterweights inside the leading edge of the control surface. This balance must be maintained (within certain tolerances) throughout the service life of the control surface, because flutter or dynamic oscillation of these surfaces in flight is sensitive to balance. Balance tolerances are always specified in the applicable aircraft Structural Repair Manual.



AM.392

Figure 8-12.–Typical balance stand.

Following the repair to (or modification of) any control surface, a balance check should be made to determine whether the specified tolerances of the control surface have been exceeded. This check is made on a specially constructed balance stand similar to the one illustrated in figure 8-12.

When a control surface is mounted on a balance stand, a downward movement of the trailing edge below the horizontal position indicates a positive (+) unbalanced moment. An upward movement of the trailing edge above horizontal indicates a negative (-) unbalanced moment.

Before making a balance check, the control surface must be complete with tab and other equipment and the final coat of paint already applied. The area must be free from drafts in order for an accurate check to be made.

TYPICAL BALANCING PROCEDURE.–The following procedure is taken from the Structural Repair Manual of a typical naval aircraft.

1. Mount the control surface on a balance stand, using the two outer hinge brackets as mounts. (See fig. 8-12.)
2. Suspend a container from the leading edge or trailing edge (as necessary) and add weight to the container until the control surface is in a horizontal position.
3. Measure the distance from the point of suspension of the container to the control surface hinge centerline. This distance is designated as X. Distances forward of the hinge line are indicated +X, and distances aft of the hinge line are indicated-X.
4. Remove the container, and determine the weight of the container and its contents. This weight is designated as W.
5. The total weight, W, multiplied by the distance, X, is equal to the calculated unbalanced moment.

EXAMPLE: A control surface in a balance stand requires a 7-pound weight (container and contents), located 6.5 inches forward of the hinge line to balance the surface in a horizontal position. This indicates an unbalanced moment of +45.5 pound/inches in the control surface. The tolerance for this control surface is +40 to +50 pound/inches; therefore, no correction is necessary. Had the tolerance for this surface been +50 to +60 pound/inches, additional counterweights would have been necessary.

AFT FUSELAGE SECTION REMOVAL AND INSTALLATION

Most single-engine jet aircraft have the engine incorporated in the fuselage. Access to the engine for removal and installation is provided by means of a removable aft section of the fuselage. All or part of other systems located in the aft fuselage section are the flight control surfaces and systems; landing gear, arresting gear, and takeoff assist systems; personnel environmental systems; hydraulic power systems; automatic flight control systems; and electrical power systems and lighting provisions. Strictly speaking, maintenance of aft fuselage sections is limited to installation and removal. Should repairs to the airframe become necessary, such work is effected in accordance with the applicable aircraft Structural Repair Manual. It is a responsibility of the AMS to remove and install aft fuselage sections, which hereafter may also be referred to as the tail section, or merely, tail.

Many of the functions associated with removal and installation of tail sections are common to nearly all aircraft having a removable tail. The procedure presented in the following paragraphs is taken from the Maintenance Instructions Manual for the A-4 (Skyhawk) and is a typical example of the steps involved. The preparatory steps are general in nature and apply to all aircraft.

REMOVAL

The first thing to do after being assigned to remove the tail section from an aircraft is to assemble all the special tools and support equipment specified in the applicable Maintenance Instruction Manual. It is futile to start the job if a needed piece of support equipment is unavailable.

The second step should be a briefing by the crew leader to the crew (four men are required on the Skyhawk) on various phases in the tail-removal sequence and the part each is expected to accomplish. All of the CAUTION and WARNING notes in the Maintenance Instructions Manual which relate to the job at hand should be read and discussed. At the end of the briefing, the crew leader (regardless of experience) should retain the Maintenance Instructions Manual containing the steps in the removal sequence so that he may use the list of steps as a checkoff list to make sure no vital step is overlooked or performed dangerously out of sequence.

Prior to the actual separation of the tail section from the main fuselage there are many preparatory steps to be taken. These include such preparations as the following:

1. Insuring approximately even fuel levels in external tanks.
2. Aileron gust lock installed.
3. Flaps are raised.
4. All ground handling safety equipment is installed.
5. All external power (hydraulic and electrical) is disconnected.
6. Removal of all necessary access doors and panels.
7. Release of air pressure from the arresting hook hold-down unit.

After completing the preparatory steps listed in the foregoing, all electrical lines, control cables, hydraulic and pneumatic tubing, oxygen system lines, and drain lines must be disconnected and stowed as per the Maintenance Instructions Manual and each of the applicable line ends or tubing openings covered to prevent contamination while separated.

In order to remove the tail section from the Skyhawk, the tailpipe clamp and tailpipe must be removed next.

With the aft fuselage installation adapter properly secured to the installation and removal trailer, position the trailer beneath the tail section. Adjust the height of the installation adapter, using hoist mechanisms on the trailer; then insert the pin to secure the arresting hook attaching fitting. Operate the trailer hoist mechanisms to raise the adapter until it contacts the fuselage aft section firmly at the supporting points. Adjust the adapter hooks on the installation adapter to align with the holes in the left- and right-hand sides of the fuselage; engage the hooks. The adapter hook straps are then adjusted to secure the tail section to the adapter. The main bolts are now ready to be removed.

The removal of the main bolts must be performed in a definite sequence. In addition, as some of the bolts that splice the two parts of the fuselage together are removed, bullet-shaped thread protectors are installed on the bolts. The thread protectors are also called aft fuselage attachment aligners, since they are also used to help align the forward and aft sections of the fuselage during reinstallation of the tail. With the thread protectors in place the aft section will not damage the splice bolt threads as the two fuselage sections are disengaged.

Before moving the tail the entire work area should be reinspected for proper disengagement of all lines, hoses, quick-disconnects, and electrical connections. If all is clear, move the tail section, supported by the trailer and installation adapter, away from the wing and fuselage forward section.

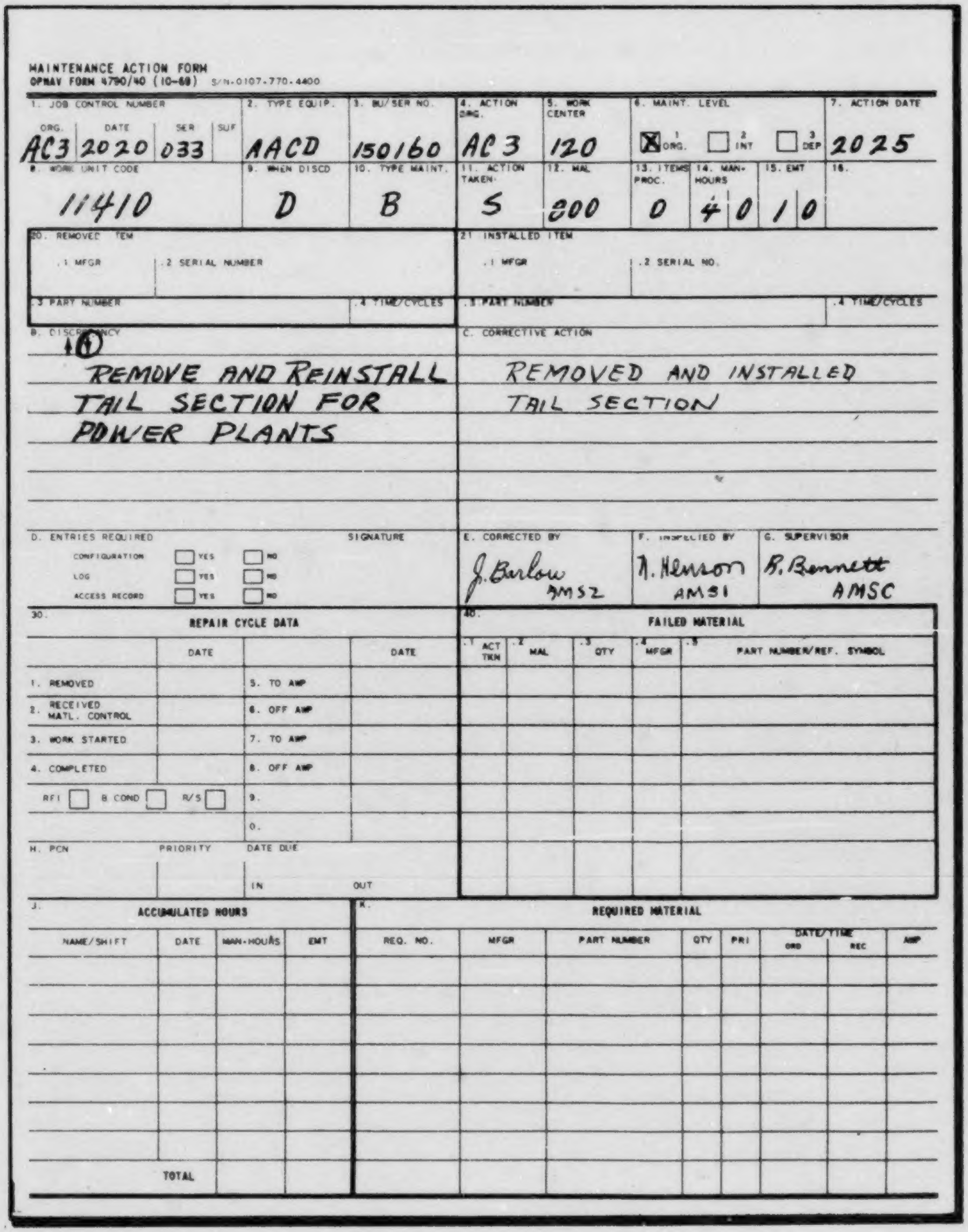
INSTALLATION

Installation of a tail section is essentially the reverse of the removal procedure. Many of the preparatory steps have to be rechecked to insure that the tail can be reinstalled safely. Just prior to actually mating the two fuselage sections an inspection should be made of the interiors of each section and all hardware which must be reconnected. Some systems such as the fire detection system should be checked out in both the forward and aft fuselage sections separately. The checking of the fire detection system components makes replacement of damaged components possible before the aft fuselage section is installed.

Extreme care must be exercised during installation of the tail to prevent damage to control cables, electrical cables, hydraulic lines, and the heat radiation shields on the lower sides of the engine.

With the aft fuselage installation adapter installed on the installation and removal trailer, and the tail section securely mounted on the adapter, move the tail section into position for attachment to the forward fuselage section.

During the actual attachment of the aft fuselage section to the forward section, another



MAINTENANCE ACTION FORM
OPNAV FORM 4790/40 (10-68) S/N-0107-770-4400

1. JOB CONTROL NUMBER ORG. AC3 / DATE 2020 / SER 033 / SUF	2. TYPE EQUIP. AACD	3. BU/SER NO. 150160	4. ACTION ORG. AC 3	5. WORK CENTER 120	6. MAINT. LEVEL ☒ 1 ORG. ☐ 2 INT ☐ 3 DEP	7. ACTION DATE 2025
8. WORK UNIT CODE 11410	9. WHEN DISCD D	10. TYPE MAINT. B	11. ACTION TAKEN S	12. MAL 800	13. ITEMS PROC. 0 / 14. MAN-HOURS 4 0 / 15. EMT 1 0	16.

20. REMOVED ITEM — .1 MFGR — .2 SERIAL NUMBER — .3 PART NUMBER — .4 TIME/CYCLES

21. INSTALLED ITEM — .1 MFGR — .2 SERIAL NO. — .3 PART NUMBER — .4 TIME/CYCLES

B. DISCREPANCY
Ⓐ
REMOVE AND REINSTALL
TAIL SECTION FOR
POWER PLANTS

C. CORRECTIVE ACTION
REMOVED AND INSTALLED
TAIL SECTION

D. ENTRIES REQUIRED — SIGNATURE
CONFIGURATION ☐ YES ☐ NO
LOG ☐ YES ☐ NO
ACCESS RECORD ☐ YES ☐ NO

E. CORRECTED BY
J. Barlow
AMS2

F. INSPECTED BY
R. Henson
AMS1

G. SUPERVISOR
R. Bennett
AMSC

30. REPAIR CYCLE DATA

	DATE		DATE
1. REMOVED		5. TO AWP	
2. RECEIVED MATL. CONTROL		6. OFF AWP	
3. WORK STARTED		7. TO AWP	
4. COMPLETED		8. OFF AWP	
RFI ☐ B COND ☐ R/S ☐		9.	
		0.	

H. PCN — PRIORITY — DATE DUE — IN — OUT

40. FAILED MATERIAL

.1 ACT TKN	.2 MAL	.3 QTY	.4 MFGR	.5 PART NUMBER/REF. SYMBOL

J. ACCUMULATED HOURS

NAME/SHIFT	DATE	MAN-HOURS	EMT
TOTAL			

K. REQUIRED MATERIAL

REQ. NO.	MFGR	PART NUMBER	QTY	PRI	DATE/TIME ORD	DATE/TIME REC	AWP

AM.5

Figure 8-13.—MAF documentation for the removal and reinstallation of a tail section.

definite sequence is employed. Many of these steps require inspection by a Quality Assurance Representative as soon as they are completed. *Once the tail section structure is properly* attached to the forward fuselage, then reconnection of all the systems between the aft and forward sections can be accomplished. Every system that can be checked must be checked for proper operation after reconnection. Other systems may require servicing prior to operation. When the crew has completed their work the Quality Assurance Representative will assure himself on final inspection that the work has been properly completed.

Figure 8-13 illustrates the use of a single copy Maintenance Action Form (MAF) for the removal of a tail section to facilitate other maintenance and the reinstallation of the same tail section.

TRANSPARENT PLASTIC ENCLOSURES

Because of the many uses of plastic materials in aircraft enclosures, optical quality (quality promoting good vision) is of great importance. These plastic materials are similar to plate glass in many of their optical characteristics. Ability to locate and identify other aircraft in flight, to land safely at high speeds, to maintain position in formation, and in some cases, to sight guns accurately through plastic enclosures, all depend upon the surface cleanliness, clarity, and freedom from distortion of the plastic material. These factors, in turn, depend entirely upon the amount of care exercised in the handling, fabrication, maintenance, and repair of the material.

Plastics have many advantages over glass for aircraft application, particularly the lightness in weight and ease of fabrication and repairs; however, they lack the surface hardness of glass, and are very easily scratched, with resulting impairment of vision. Care must be exercised while servicing all aircraft to avoid scratching or otherwise damaging the plastic surface.

Specific procedures are described later in this section for light maintenance; however, the following general rules should be emphasized:

1. Transparent plastic materials should be handled only with clean cotton gloves.
2. The use of harmful liquids as cleaning agents should be avoided.
3. Fabrication, repair, installation, and maintenance instructions must be closely followed.
4. Operations which might tend to scratch or distort the plastic surface must be avoided. Care must be taken to avoid scratching plastic surfaces with finger rings or other sharp objects.

Just as woods split and metals crack in areas of high, localized stress, plastic materials develop, under similar conditions, small surface fissures called CRAZING. These tiny cracks are approximately perpendicular to the surface, very narrow in width, and usually not over 0.01 inch in depth. These tiny fissures are not only an optical defect, but also a mechanical defect, inasmuch as there is a separation or parting of material.

Crazing may be caused by improper cleaning, improper installation, improper machining, or cold forming. Once a part has been crazed, neither the optical nor mechanical defect can be removed permanently; therefore, prevention of crazing is most necessary.

CLEANING PLASTIC SURFACES

For exterior surfaces, flush with plenty of water, using the bare hand gently to feel and dislodge any dirt, sand, or mud. The plastic is then washed with a mild soap, specification P-S-560 and clean water. NOTE: Water containing dirt and abrasive materials may scratch the plastic surface.

A clean soft cloth, sponge, or chamois may be used to carry the soap and water to the plastic. The cloth, sponge, or chamois should not be used for scrubbing; use the hand method as described for removing dirt or other foreign particles.

Dry with a clean damp chamois, a soft clean cloth, or soft tissue by blotting the surface until dry. Rubbing the surface of the plastic will induce (build up) an electrostatic charge that attracts dust particles to the surface. If the surface does become charged, patting or gently blotting with a damp, clean cloth will remove this charge as well as the dust.

To clean interior plastic surfaces, dust the surface lightly with a soft cloth. Do not wipe the surface with a dry cloth. Next, wipe carefully with a soft damp cloth or sponge. Keep the cloth or sponge free from grit by rinsing it frequently in clean water.

Cleaning and polishing compound, Specification P-P-560, may be used to remove grease and oil. Apply the compound with a soft cloth, rub in a circular motion until clean, and polish with another soft cloth.

REMOVAL OF SCRATCHES

The AMS is required to remove and install canopies, escape hatches, and other aircraft structures that contain plastic sections. Great care must be taken to protect the finish of the plastic. Plastic is very soft as compared to other aircraft structural materials. The surface is easily scratched or damaged, and should be protected by the use of proper protective covers and storage racks which are provided by the aircraft manufacturer or are manufactured locally. It is easier to avoid scratches than to remove them. It is possible, however, to restore even a badly scratched surface to a good finish by buffing and sometimes sanding.

Aircraft Maintenance Instructions Manuals specify limits on the length, width, and depth of cracks, and in what areas they are allowed. These measurements are normally made by the use of an optical micrometer. If a scratch exceeds the specified limitations, the surface must be replaced.

Before starting to sand or buff, be sure the plastic surface is clean. The buffing wheels and compounds should also be free of dirt and grit to avoid seriously scratching the surface during the polishing operation. If the buffing wheels have been used before, remove any hardened tallow by running the wheels against a metal edge.

It is important to remember that most plastic enclosures are thermoplastic and soften when heated. The friction of sanding or buffing too long or too vigorously in one spot can generate enough heat to soften or burn the surface. Also, plastic that has been deep-drawn, or formed to compound curvatures, has a tendency to return to its original thickness when excessive heat is applied. The best procedure is to keep either the wheel or plastic constantly in motion relative to one another. Keep the pressure against the wheel to a minimum, and change the direction of buffing often.

Briefly, the procedure for removing scratches is as follows:

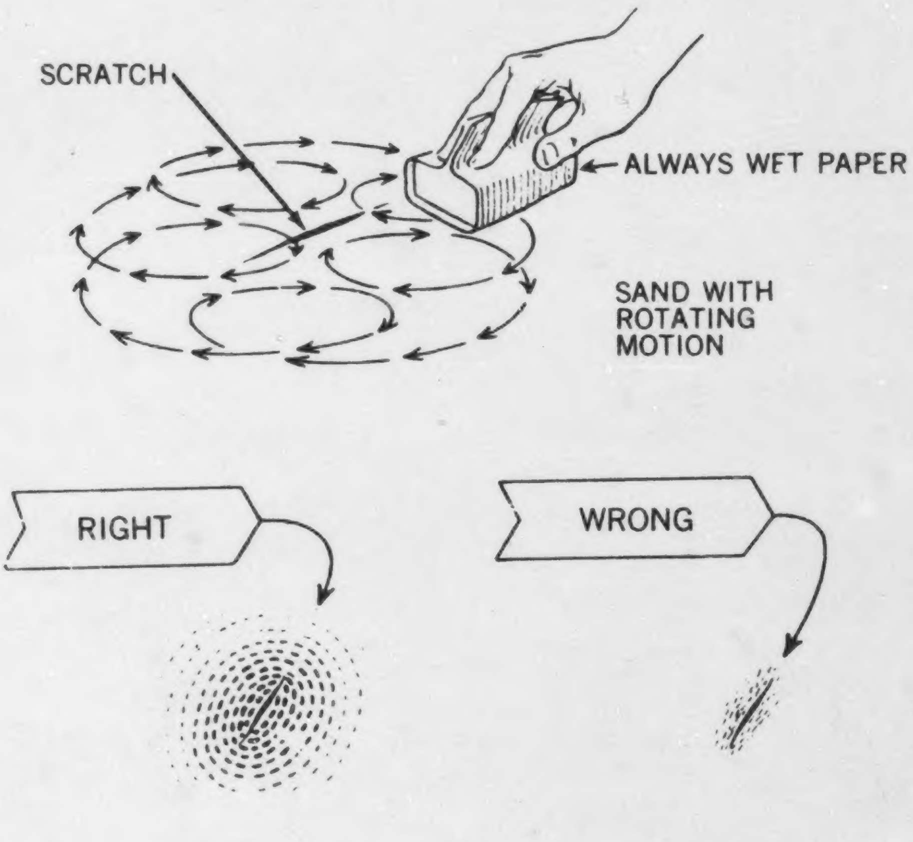
A single deep scratch or imperfection is reduced by sanding to a number of small, shallow scratches. These scratches, in turn, are reduced to a larger number of still smaller scratches on a buffing wheel to which a fine abrasive is applied. These finest scratches are further reduced or filled in with tallow or wax. A final buffing or polishing brings the surface to a high gloss. The depth of scratch will determine how many of these operations are necessary. However, each step in the process must be performed thoroughly, or subsequent polishing will not remove scratches left by previous operations.

It is obvious that sanding and buffing cause thickness variations in the plastic around the scratch. If skillfully done, these operations will cause only minor optical distortions which will not be serious in most applications. Distortion may be reduced by gently polishing and feathering a fairly large area around the scratch. In critical optical sections, however, even minor distortions may cause serious deviations in sighting. Such sections, even though scratched, should not be sanded or buffed. If necessary, these sections are replaced.

Sanding

Transparent plastics should never be sanded unless absolutely necessary, and then only when surface scratches, which may impair vision, are too deep for removal by buffing.

When sanding is necessary, the finest smallest grit abrasive paper that will remove the scratch or other defect should be used first. Normally, the AMS will never need abrasive paper coarser than No. 320A; however, abrasive paper as coarse as No. 240A may be used if the situation warrants. The abrasive paper is wrapped around a felt-covered, wooden or rubber block and the defective area rubbed lightly, using plain water or water with a 2 percent soap content as a



DO NOT SAND UNLESS ABSOLUTELY NECESSARY TO REMOVE DEEP SCRATCHES. HOLD SANDPAPER BY SMOOTH RUBBER OR WOODEN BLOCK. SAND OVER A WIDE AREA TO PREVENT OPTICAL DISTORTIONS. EXCESS PRESSURE IN SANDING OR BUFFING WILL BURN PLASTIC.

AM.393

Figure 8-14.—Proper method of sanding plastic.

lubricant. Use circular strokes as shown in figure 8-14. Never use a straight back-and-forth motion. Sand an area about two or three times the length of the defect in order to minimize optical distortion and excessive thinning of the plastic. The initial sanding should then be followed by similar treatments, using successively finer grades of sandpaper in the following sequence: Nos. 400A, 500A, and 600A. Wash the plastic after each operation. During each step, the deeper scratches left by the preceding grade of abrasive should be removed.

Buffing

In order to remove the fine, hairline scratches caused by sanding, transparent plastic may be buffed. It is often possible to remove scratches by buffing alone, provided the scratches are not too deep.

There are a number of standard commercial buffing compounds satisfactory for use on transparent plastic enclosures. They are usually composed of very fine alumina or similar abrasive in combination with wax, tallow, or grease binders. They are available in the form of bars or tubes for convenience in applying to the buffing wheel.

Plain tallow is often applied to the buffing wheel. It may be used in addition to buffing compound, or may be used alone. In the latter case, tallow functions similar to wax inasmuch as it fills in hairline scratches and gives a high gloss to the surface.

Buffing wheels are made of cotton cloth or felt. For removing scratches caused by sanding, an "abrasive" wheel and a "finish" wheel are needed. (See fig. 8-15.) The abrasive wheel, which is relatively hard and to which buffing compound is applied, is used for removing the deeper scratches. The finish wheel, which is soft, is then used to bring the plastic to a high polish. Both wheels are made up of numerous layers of cloth discs, but the abrasive wheel is made hard by several rows of stitches, as shown in the illustration. The finish wheel is unstitched with spacers (washers) mounted between every fourth or fifth cloth disc.

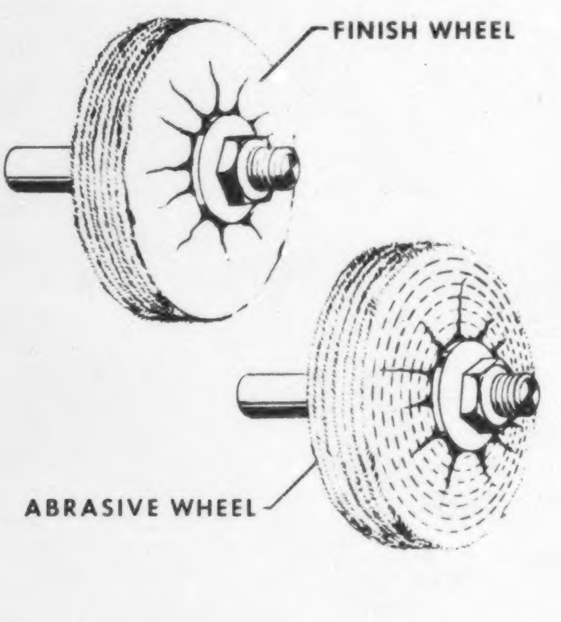


Figure 8-15.—Buffing wheels.

Power for turning the buffing wheel may be supplied by mounting it in a portable drill, as shown in figure 8-16, or a pedestal-type machine similar to the one shown in figure 8-17 may be used.

At the start of each buffing operation, the plastic must be clean and dry. Some of the buffing compounds now available will leave the surface clean so that washing is not necessary. Where necessary, however, washing should follow each step in buffing.

If a panel has been sanded previously or is deeply scratched, the abrasive wheel should be used first.

Apply fresh compound to the wheel and buff lightly along and across all scratches. Keep the plastic or wheel in motion with relation to each other to prevent generating too much heat, thus damaging the plastic.

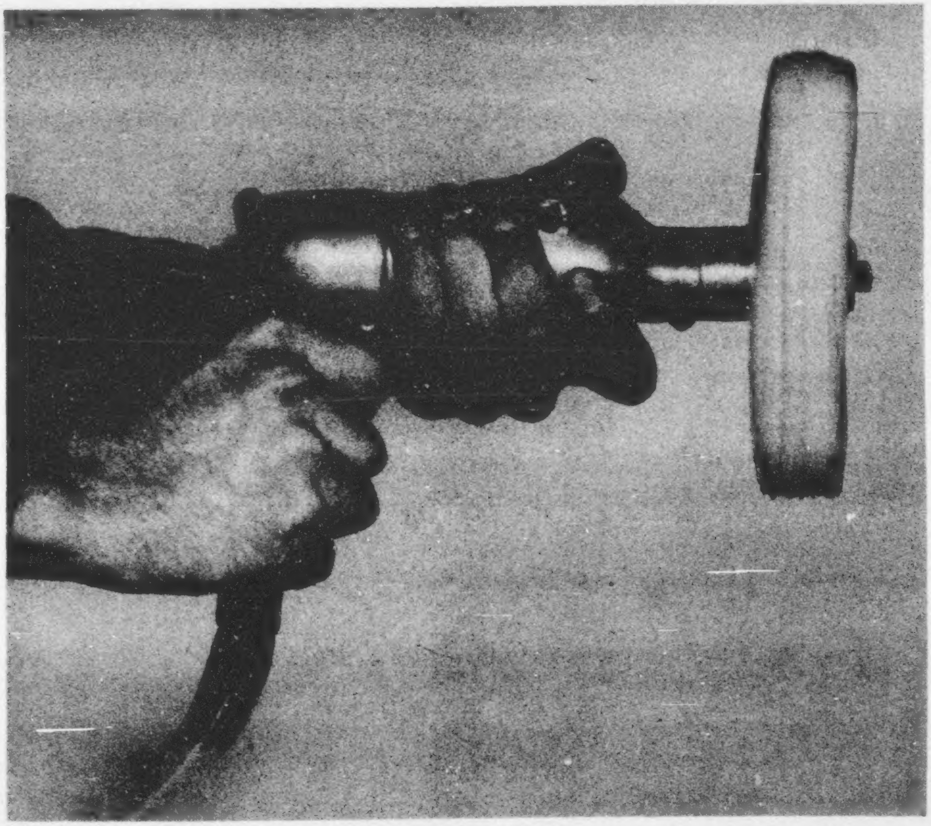
Complete the buffing operation by using the finish wheel, bringing the plastic surface to a high gloss.

After all scratches have been removed with the finish wheel, a coat of wax should be applied by hand.

CAUTION: Hand polishing is recommended in critical vision areas. Overheating transparent plastic, by buffing, induces internal stresses and optical distortions.

INSTALLATION OF PLASTIC PANELS

There are a number of methods of installing transparent plastic panels in aircraft, some of which are shown in figures 8-18 through 8-21. Which method the aircraft manufacturer uses depends upon the position of the panel in the aircraft, the stresses to which it will be subjected, and a number of other factors. In installing a replacement panel, always follow the same mounting method used by the manufacturer of the aircraft.



AM.395

Figure 8-16.—Buffing wheel mounted in portable drill.

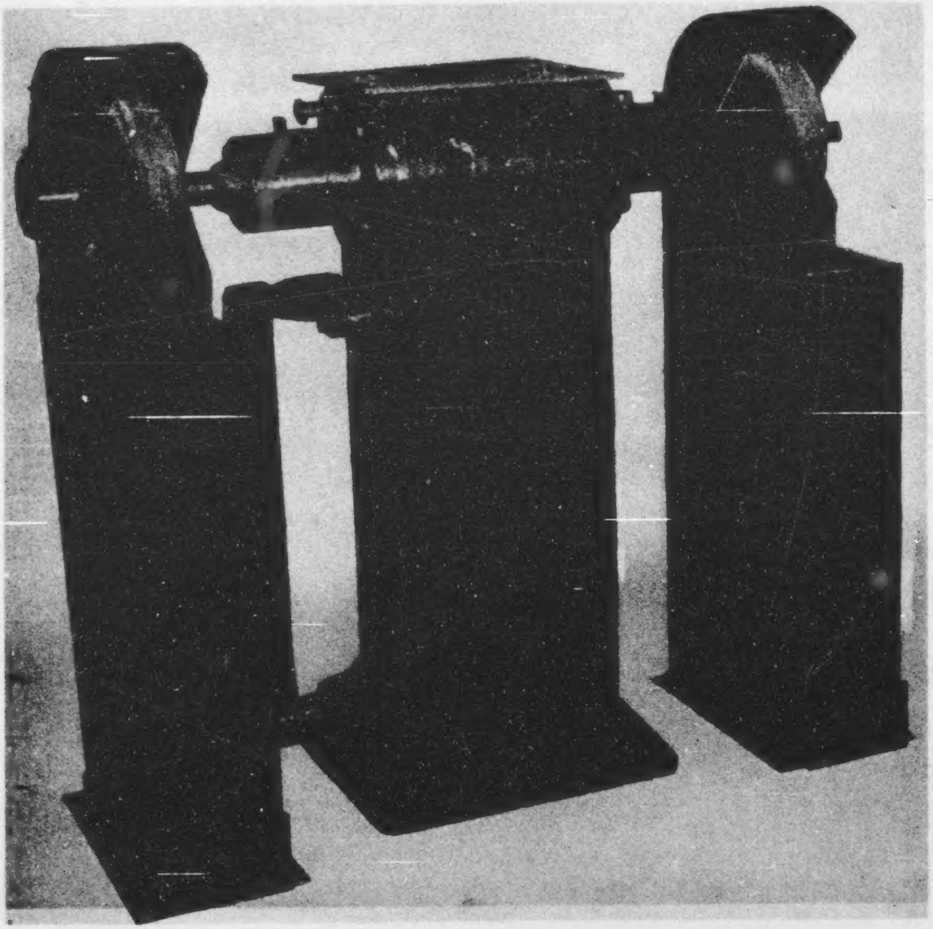
The following general rules apply to all types of mountings. Fitting and handling should be done with masking paper in place, although the edges of the paper may be peeled back slightly and trimmed off for installation.

Since transparent plastic is brittle at low temperatures, installation of panels should be done at normal temperatures.

Plastic panels should be mounted between some type of gasket material to make the installation waterproof, to reduce vibration, and to help distribute compressive stresses on the plastic. Minimum packing thickness is 1/16 inch. Rubber, fiber glass impregnate, and nylon are the most commonly used gasket materials.

Since plastic expands and contracts three times as much as metal, suitable allowances for dimensional changes with temperature must be made. Minimum clearances between the frame and the plastic are listed in NavAir 01-1A-12. Clearance should be equally divided on all sides.

Screw torquing procedures should be in accordance with the applicable Maintenance Instructions Manual. Plastic panels should not be installed under unnatural stresses. Each screw must be torqued as specified to enable it to carry its portion of the load. If a plastic panel is installed in a binding or twisted position and screws are not torqued correctly, the plastic panel may fail while the aircraft is undergoing



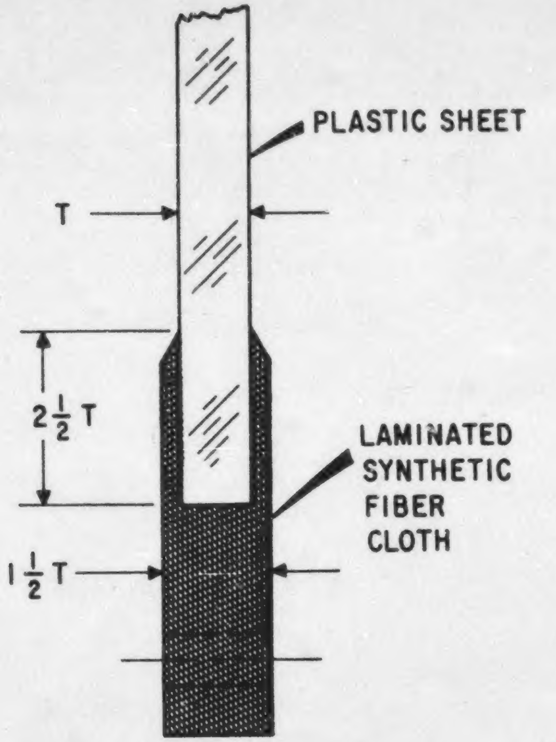
AM.396

Figure 8-17.—Pedestal type buffer with stitched and unstitched cloth wheels.

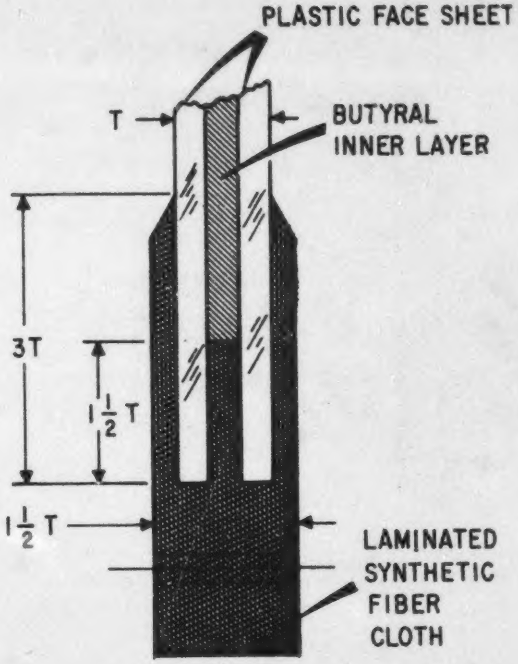
normal taxiing and flight operations.

During the removal of a plastic panel, there may be several different lengths of screws to be removed. The AMS will save a lot of time if he acquires the habit of keeping screws separated. An easy way to do this is to draw a diagram of the panel on cardboard. Puncture each screw hole, with an awl, through the cardboard. As each screw is removed from the panel, it is installed in its respective position on the cardboard. This is done with each screw as it is removed.

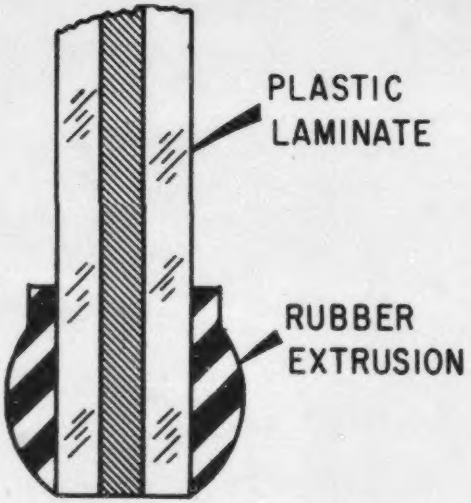
During installation of the panel, each screw is removed from the cardboard and reinstalled in the same hole from which removed until all of the screws are reinstalled.



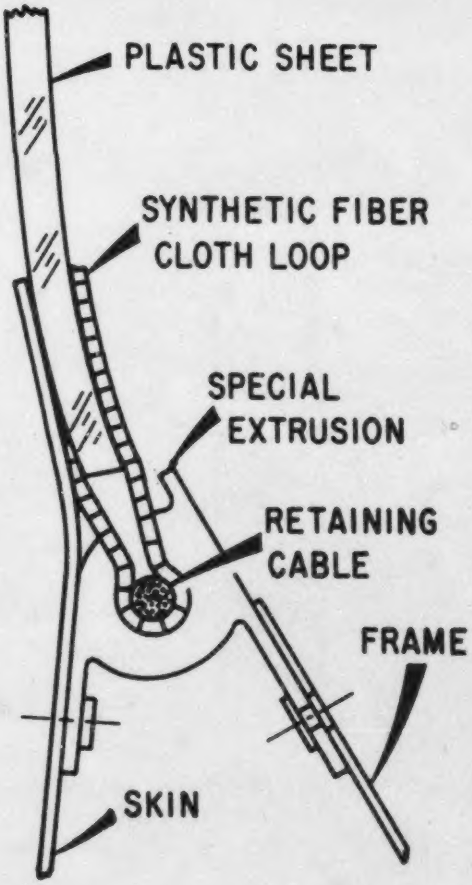
AM.397
Figure 8-18.—Approved edge attachment for solid plastic.



AM.398
Figure 8-19.—Approved edge attachment for laminated plastic.



AM.399
Figure 8-20.—Typical sighting dome attachment.



AM.400
Figure 8-21.—Typical loop edge attachment.

CHAPTER 9

LANDING WHEELS, TIRES, AND TUBES

WHEELS

The AMS must have the knowledge and professional ability to change wheel and tire assemblies, repack and replace wheel bearings, and build up tires, as well as practice the safety precautions related to these procedures. Generally, the wheels require only normal upkeep and take up little of the AMS' time; however, he may be stationed where wheel assemblies frequently come in contact with salt water or salt air. In an area such as this, the AMS will spend a considerable amount of time stripping paint and treating the wheels to help control or eliminate corrosion. Wheels are removed from aircraft frequently for tire changes, inspections, lubrication of wheel bearings, and inspection of the wheel brakes. Familiarity with the various types of wheels, their construction features, and how they are properly installed on the aircraft are therefore highly important items.

This section describes the types of wheels currently used on naval aircraft, illustrates the various components of a typical wheel assembly, and describes the procedure for removing and installing a wheel properly. Installation of each component in its proper order in the wheel hub, and correct adjustment of the wheel bearings are especially important items.

Aircraft landing wheels are made from either aluminum alloys or magnesium alloys. Both of these materials provide a strong, lightweight wheel, requiring very little maintenance.

Wheels used on naval aircraft are of two general types—the DIVIDED type and the DEMOUNTABLE FLANGE type. Both of these designs make tire changing a fairly simple operation.

Some wheels are designed for use with tires and tubes while others are designed for use with tubeless tires. Those designed for use with tires and tubes have knurled flanges to prevent tire slippage on the wheel. Wheels for use with tubeless tires have the wheel sections sealed by an O-ring and employ special valves which are a part of the wheel.

DIVIDED (SPLIT) TYPE WHEEL

Figure 9-1 illustrates a typical divided (split) type wheel. This type of wheel is divided into two halves, which are held together by bolts and nuts. The two halves are sealed by an O-ring on wheels designed for use with tubeless tires. Each wheel half is statically balanced so that any two opposite halves of the same size and type (part

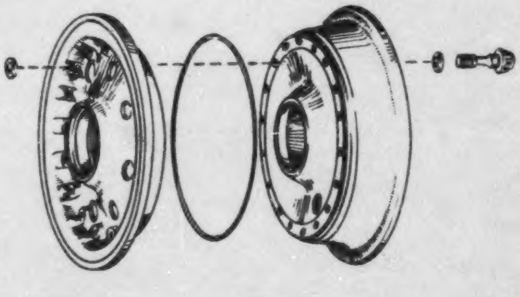
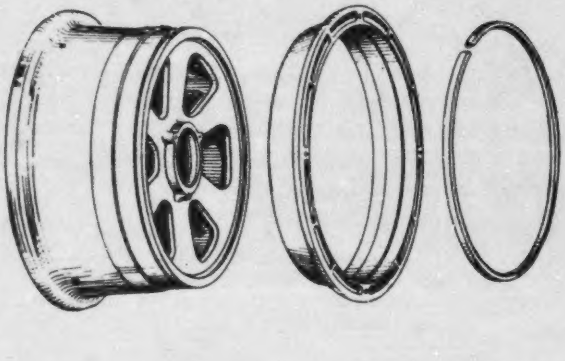

AM.401

Figure 9-1.—Typical divided (split) type wheel.

no.) may be joined together to form one wheel assembly. Thus, if the outboard half of a wheel is damaged beyond repair, a new outboard half can be drawn from supply and assembled to the old inboard half. This type of wheel is used on nose, main, and tail gears.

DEMOUNTABLE FLANGE TYPE WHEEL

The demountable flange landing wheel is made so that one flange of the wheel can be removed for changing the tire. The flange is held in place on the assembled wheel by a lockring or bolts. The wheel is balanced with the flange mounted on the wheel, and both the wheel and flange are marked. To insure proper balance of the wheel when assembling, these two marks should be lined up together. Figure 9-2 illustrates a typical demountable flange type landing wheel. This type wheel is more commonly used on the main landing gear.



AM.402

Figure 9-2.—Typical demountable flange type wheel.

Wheels are further classified into the following types:

Type I—Smooth contour.
Type II—High pressure.
Type III—Low pressure.
Type IV—Extra low pressure.
Type VI—Low profile.
Type VII—Extra high pressure.
Type VIII—Extra high pressure (low profile).

These designations refer to the features of construction and the types of tire casings with which they are used. The dimensions by which wheels are identified are not necessarily the dimensions of the wheels themselves, but refer to certain dimensions of the tire. Size designations are discussed in the section on tires.

Similarity of one wheel to another in size and shape is no proof that the wheels can be interchanged, since one wheel may be designed for heavy duty while the other one is designed to carry a lighter load. Also, one wheel may be designed for use with an entirely different type of brake assembly.

TYPICAL WHEEL ASSEMBLY

A complete wheel assembly is shown in figure 9-3. The wheel casting (6) is the basic unit of the wheel assembly. It is to this part that all other components of the assembly are assembled and upon which the tire is mounted.

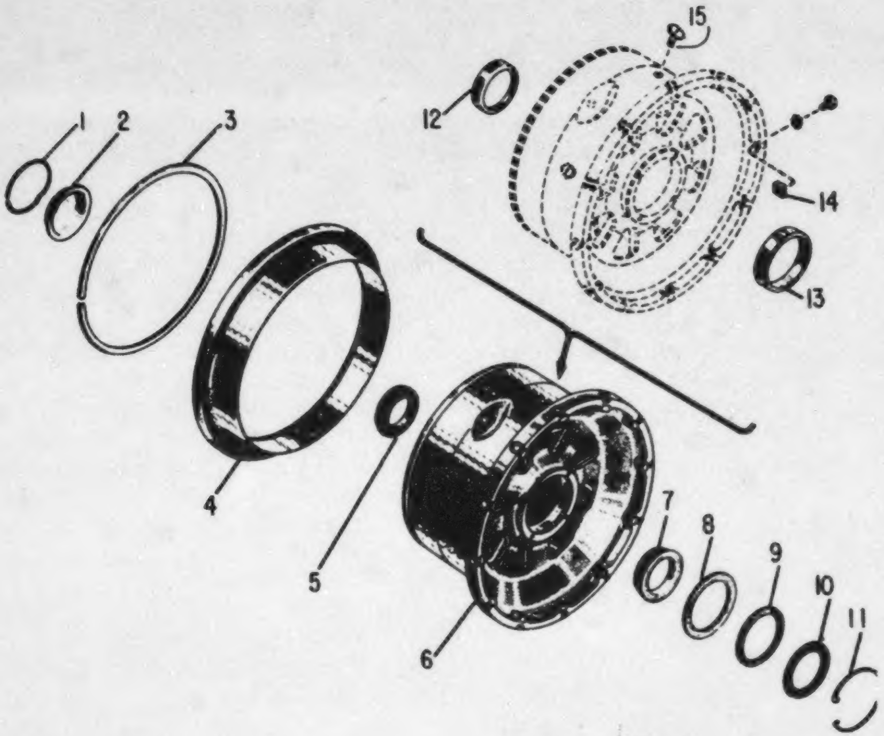
The demountable flange (4) is assembled to the wheel with the chief purpose being to simplify tire removal and installation. The demountable flange lockring (3) secures the flange to the wheel. It is fitted into a groove in the wheel casting.

The bearing cups (12) and (13) are shrink-fitted into the hub of the wheel casting and are the parts on which the bearings ride. The bearings (5) and (7) are the tapered roller type. Each bearing is made up of a cone and the rollers. This type bearing absorbs side thrust as well as radial loads and landing shocks. Bearings must be cleaned and repacked with grease periodically, as discussed later in the chapter.

A three-piece grease retainer retains the grease in the inboard bearing and keeps out dirt and moisture. It is composed of a felt seal (9) and an inner and outer closure ring (8) and (10). A lockring (11) secures the assembly inside the wheel hub.

The hubcap (2) seals the outboard side of the hub. It is also secured with a lockring (1); however, on some aircraft the hubcap is secured with screws.

All wheels designed for use on the main landing gear are equipped with braking components. These components are attached to the wheel casting and may consist of either a



AM.403

1. Hubcap lockring.
2. Hubcap.
3. Demountable flange lockring.
4. Demountable flange.
5. Outboard bearing.
6. Wheel casting.
7. Inboard bearing.
8. Inboard bearing closure ring.
9. Inboard bearing felt seal.
10. Inboard bearing closure ring.
11. Inboard bearing closure lockring.
12. Outboard bearing cup.
13. Inboard bearing cup.
14. Disc drive key.
15. Fusible plug.

Figure 9-3.—Typical wheel assembly.

brake drum or brake drive keys. The wheel in figure 9-3 is equipped with drive keys (14). This type wheel is designed for use with disc type brakes. Those equipped with brake drums are designed for use with expander tube brakes, or the old shoe type brake which is no longer used on naval aircraft.

The trend in the armed forces seems to be larger and faster aircraft, which means heavier loads and higher landing speeds. Friction caused by long rollouts, taxiing, etc, cause heat to be absorbed by the wheel. Possible wheel failure may occur and cause severe damage to equipment and personnel. To counteract this situation, aircraft manufacturers have developed a safety device called a fusible plug. The fusible plug (15) contains an alloy which will melt and permit the tire to deflate in the event the wheel is exposed to excessive heat from overbraking or other causes. This release of air pressure will prevent damage to personnel or equipment. Wheels which contain fusible plugs should have a metal tag affixed which reads, "Fusible Plugs Installed."

BALANCING OF WHEELS

Wheel assemblies are statically balanced at the time of their manufacture. The method of balancing is such that the limits of the assembly imbalance will not be exceeded by changing major portions of the rotating assembly, such as brake drums or demountable flanges. Split wheels are balanced so that assembling the wheel halves in alternate positions or assembling halves of different wheels together will not unbalance the assembly beyond the specified limits. Balance weights are securely attached in such a manner that the wheel performance is not impaired. Any weights which have been added to a wheel to bring it within proper balance should not be removed. However, if a wheel has been rendered out of balance due to loss, breakage, or accidental removal of the balance weights, the wheel must be rebalanced in accordance with existing instructions.

WHEEL MAINTENANCE AND INSPECTION

The AMS removes wheels from aircraft periodically for a thorough inspection. Wheels are cleaned, using a suitable solvent, prior to inspection. The wheels are then inspected for corrosion, cracks, distortion, condition of paint or protective coatings, and checked for evidence of overheating due to braking action.

CAUTION: When an aircraft wheel is to be removed from the aircraft, the air must be removed from the tire prior to removing the wheel. This precaution must be taken because of the possibility that the bolts in split type wheels might have been sheared from landing, thus causing the wheel halves to separate when the axle nut is removed. In the past, several people have been killed by, their failure to remove the air from the tire before removing the axle nut.

Wheel bolts used to fasten divided (split) type wheels are inspected for cracks or condition. This inspection is normally performed using the magnetic particle inspection in accordance with applicable directives.

Braking surfaces are checked for looseness and for excessive or uneven wear. Wheel bearings are cleaned with an approved solvent. After the wheel bearings are cleaned and inspected (in that order) they are lubricated with Specification MIL-G-81322A, wide temperature range grease. Wheel bearings may be lubricated either by pressure equipment or hand methods as illustrated in figures 9-4 and 9-5. However, the pressure method is recommended since it is easier, faster, reduces the possibility of contamination, and, when utilized correctly, will assure a more even distribution of grease within critical areas. Felt grease retainers are cleaned or replaced if saturated with lubricant. Bearing cups are inspected for wear and damage.

NOTE: Insure bearings are completely dry prior to packing with lubricant. Water or condensation will cause bearings to rust.

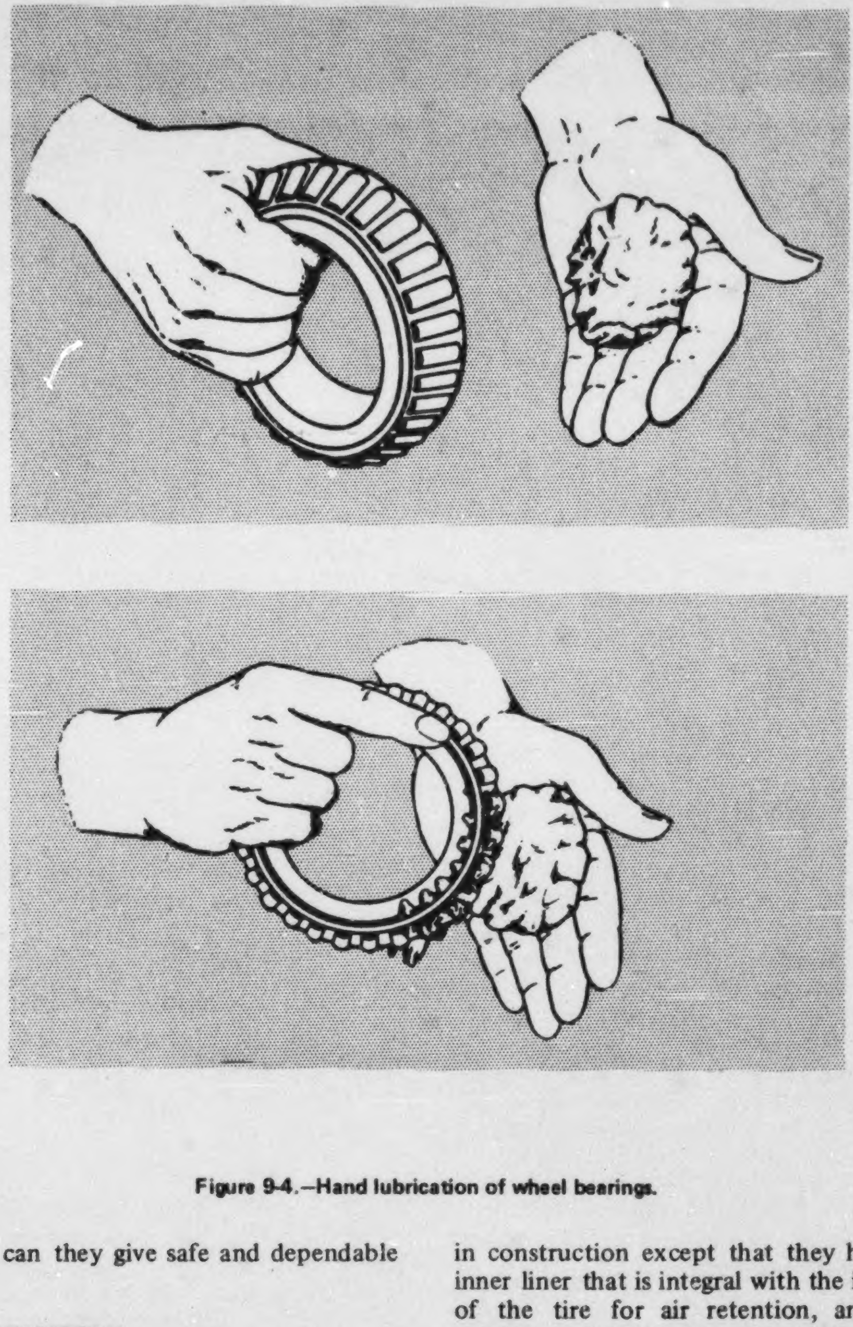
Fusible plugs are inspected to detect fused or partially fused plugs. Figure 9-6 gives examples of fusible plugs; the top row shows usable plugs, the second row partially fused plugs, and the bottom row illustrates fused plugs. Wheels containing either partially fused or fused plugs must have all plugs contained in the wheel replaced. Then the wheel must be inspected for damage using the procedures listed in the applicable Overhaul Instructions Manual for that specific wheel.

In reinstalling the wheel on the aircraft, proper adjustment of the bearings is extremely important. The procedure is as follows:

1. Tighten the axle nut while spinning the wheel by hand.
2. When the wheel no longer spins freely, back off the axle nut one castellation (1/6 turn). When properly installed and adjusted, the wheel will turn freely, but will have no sidewise movement. (This procedure may vary from one aircraft to another; the AMS must refer to the applicable Maintenance Instructions Manual.)
3. Safety the axle nut, and install hubcap and lock it in place.

AIRCRAFT TIRES

Proper care and maintenance of tires have always been important items in aircraft maintenance; however, with the development and use of the fast-landing aircraft of today, careful tire maintenance has become increasingly important. Aircraft tires are built to withstand a great deal of punishment, but only by proper care and



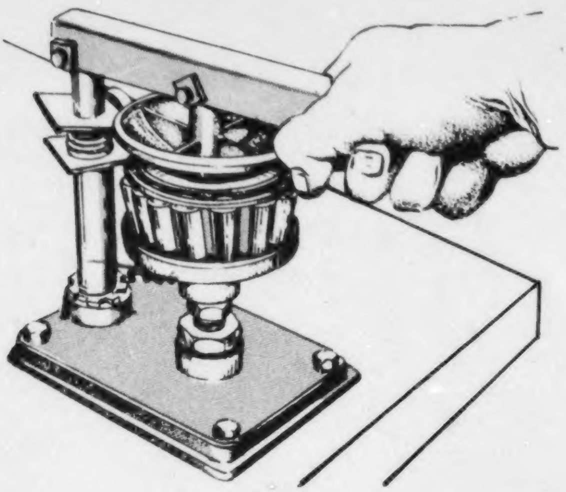
AM.404

Figure 9-4.—Hand lubrication of wheel bearings.

maintenance can they give safe and dependable service.

TIRE CONSTRUCTION

Figure 9-7 shows the construction details of a tube-type aircraft tire. Tubeless tires are similar in construction except that they have a rubber inner liner that is integral with the inside surface of the tire for air retention, and they also employ materials and construction in the bead area designed to form a seal with the wheel flange. Wear indicators (tread depth holes located in the tread area or lands located in the



AM.1215
Figure 9-5.—Pressure lubrication of wheel bearings.

bottom of the tread grooves) have been incorporated into select tires as an aid in measuring tread wear.

The CORD BODY consists of multiple layers of nylon with individual cords arranged parallel to each other and completely encased in rubber. The fabric, therefore, has all its strength in only one direction. Each layer of coated fabric constitutes one ply of the cord body. Adjacent cord plies in the body are assembled with the cords crossing nearly at right angles to each other. This arrangement provides a strong and flexible construction that distributes impact shocks over a wide area. The main function of the cord body is to give the tire tensile strength to resist internal pressures and to maintain tire shape. It must be able to withstand severe flexing, heat, and impact shocks during normal tire operations.

The TREAD is a layer of rubber on the outer circumference of the tire. It provides the wearing surface and protects the cord body underneath from abrasion, cuts, bruises, and moisture.

The SIDEWALL is an outer layer of rubber adjoining the tread and extending down to the beads. Like the tread, it protects the cord body from abrasion, cuts, bruises, and moisture.

The BEADS are multiple strands of high tensile strength steel wire imbedded in rubber and wrapped in strips of open weave fabric. The beads hold the tire firmly on the rims and serve as an anchor for the fabric plies turned up around the bead wires.

The CHAFING STRIPS are one or more plies of rubber-impregnated woven fabric wrapped around the outside of the beads. They provide additional rigidity to the bead construction and prevent the metal wheel rim from chafing the tire. Tubeless tires have an additional ply of rubber over the chafing strips which functions as an air seal.

The BREAKERS are one or more plies of cord or woven fabric impregnated with rubber. When used, they are located between the tread rubber and the cord body, and provide extra reinforcement to prevent bruise damage to the tire. Breakers are not considered part of the cord body.

Tread Patterns

The tread is a layer of rubber on the outer circumference of the tire. There are four designs of tread patterns available for use on naval aircraft.

The tread patterns may be any of the following designs.

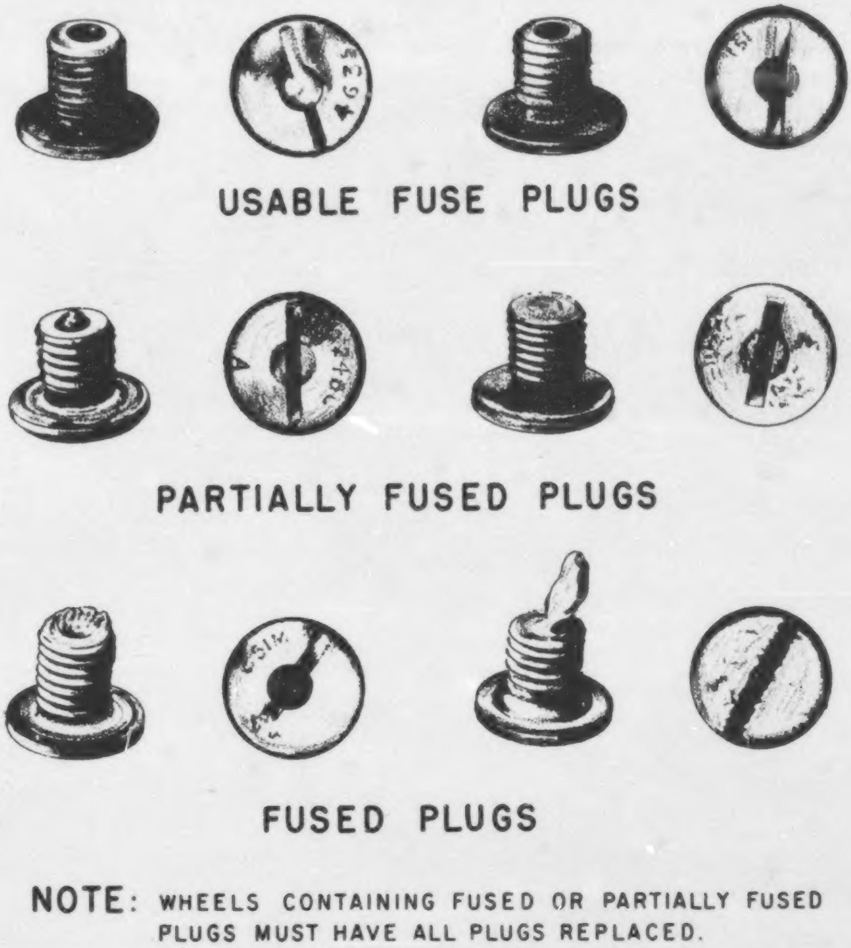
1. Plain. A plain tread is one with a smooth uninterrupted surface.
2. Nonskid. A nonskid tread is any grooved or ribbed type tread.
3. Ribbed. A ribbed tread pattern is one having three or more continuous circumferential ribs.
4. Channel. Channel tread tires are heavier than the respective standard types to reduce wheel shimmy and improve ground handling of aircraft.

Tread Construction

The tread construction will be one of the following types.

NOTE: Other tread types may be provided under specific circumstances or as required by applicable MS standards or drawings.

1. Rubber tread. A rubber tread is constructed from 100 percent new (no reclaim)


USABLE FUSE PLUGS
PARTIALLY FUSED PLUGS
FUSED PLUGS
NOTE: WHEELS CONTAINING FUSED OR PARTIALLY FUSED PLUGS MUST HAVE ALL PLUGS REPLACED.

AM.406

Figure 9-6.—Fusible plugs.

rubber. It may be new natural rubber, new synthetic material, or a blend of new natural and new synthetic materials.

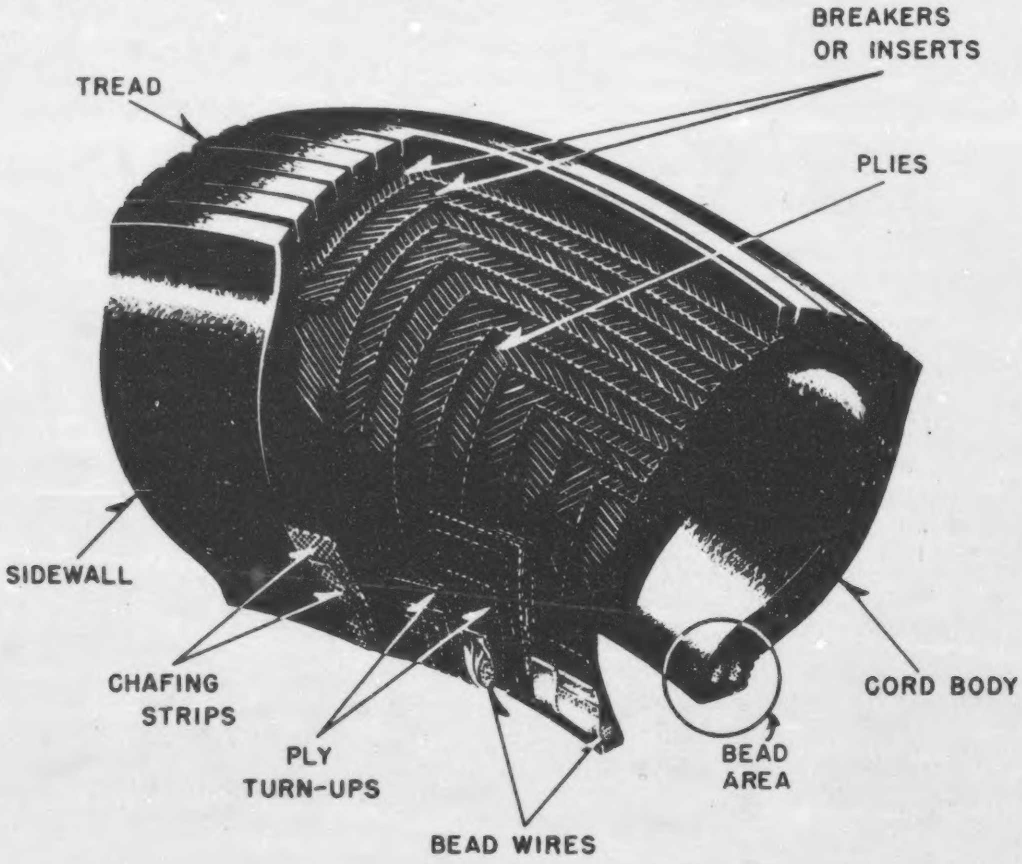
2. Cut-resistant tread. A cut-resistant tread is one which has improved cut-resistant properties that are imparted to the tire by incorporating into the undertread a barrier that resists penetration of cutting objects.

3. Reinforced tread. A reinforced tread is one constructed with fabric cord or other reinforcing materials as an integral part of the tread. (See fig. 9-8.)

4. Reinforced cut-resistant tread. A reinforced cut-resistant tread is one that combines the features of both the cut-resistant and reinforced-tread design.

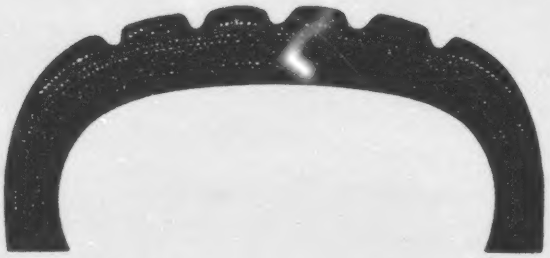
Ply Rating

The reference to the number of cord fabric plies in a tire has been superseded by the term "ply rating." This is used to identify a given tire



AM.406

Figure 9-7.—Typical aircraft tire construction.



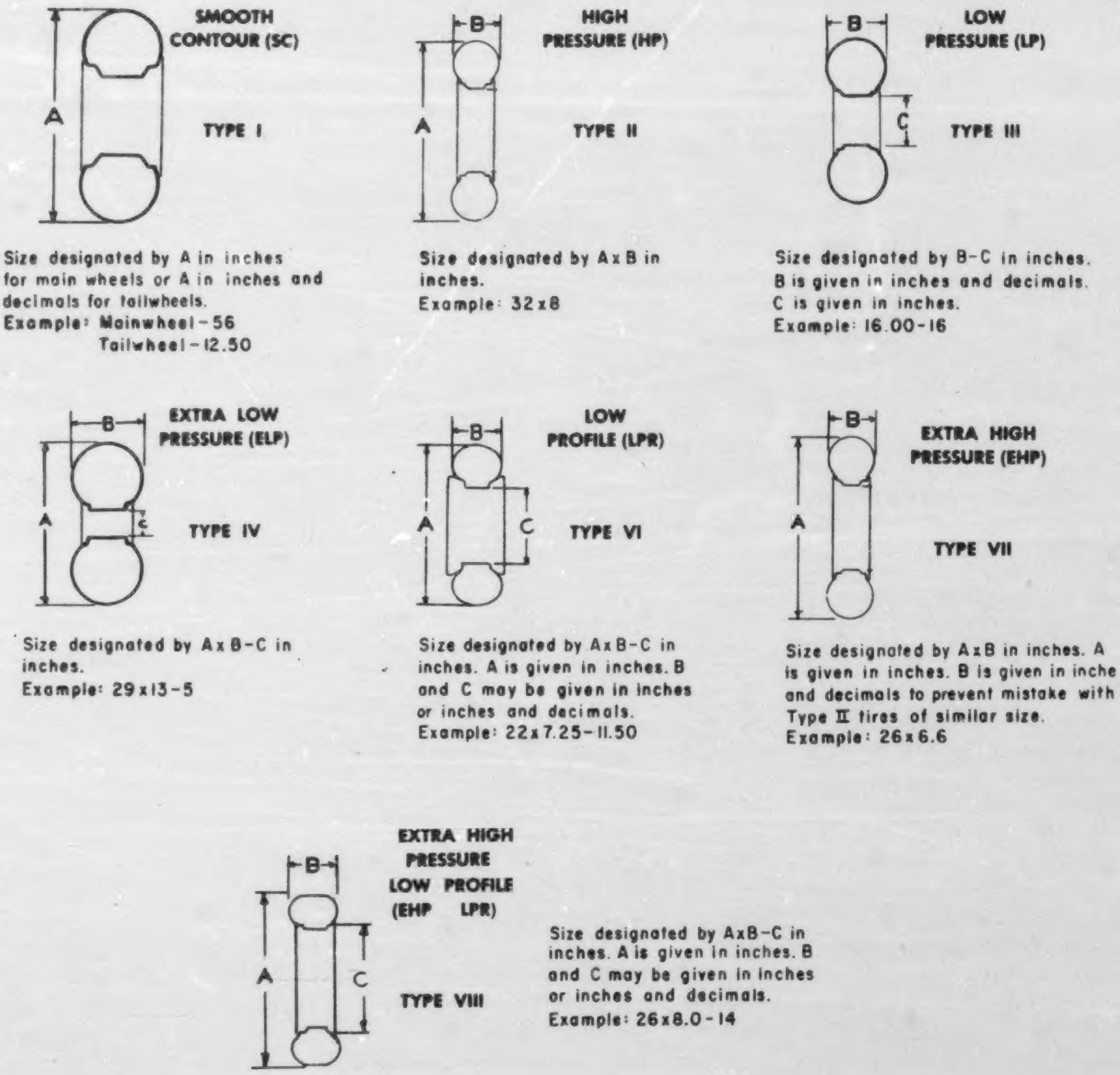
AM.1216

Figure 9-8.—Reinforced-tread construction.

with its maximum recommended load for specific types of service. It does not necessarily represent the number of cord fabric plies in a tire. Most nylon cord tires have ply ratings greater than the actual number of fabric plies in the cord body.

Type and Size Designation

There are seven types of tires used on aircraft now in service. Figure 9-9 illustrates the various types and how the size of each is designated. Dimension A in the illustration is the outside diameter of the tire. Dimension B is the cross-sectional width of the tire at its widest point. Dimension C is the inside diameter of the tire.



Size designated by A in inches for main wheels or A in inches and decimals for tailwheels.
Example: Mainwheel - 56
Tailwheel - 12.50

Size designated by A x B in inches.
Example: 32 x 8

Size designated by B-C in inches. B is given in inches and decimals. C is given in inches.
Example: 16.00-16

Size designated by A x B-C in inches.
Example: 29 x 13-5

Size designated by A x B-C in inches. A is given in inches. B and C may be given in inches or inches and decimals.
Example: 22 x 7.25-11.50

Size designated by A x B in inches. A is given in inches. B is given in inche and decimals to prevent mistake with Type II tires of similar size.
Example: 26 x 6.6

Size designated by AxB-C in inches. A is given in inches. B and C may be given in inches or inches and decimals.
Example: 26x8.0 - 14

AM.408

Figure 9-9.—Types and size designation of tires.

Identification Markings

The AMS should be familiar with the markings on the sidewall of tires. Some of this information is needed to facilitate completion of Maintenance Action Forms (MAF) and other required maintenance forms. Each marking which is engraved or embossed on the sidewall for identification purposes is discussed in this section.

SIZE AND TYPE.–The size of the tire is indicated as previously explained, and the type is indicated by the Roman numeral designated for that type of tire.

PLY RATING.–On some tires "ply rating" is abbreviated as "PR".

CORD BODY MATERIAL.–Type of material used in the carcass if other than nylon.

DATE OF MANUFACTURE AND SERIAL NUMBER.–The date of manufacture of the tire is included in the serial number. The serial number consists of a maximum of 10 positions. The first four positions indicate the date of manufacture in the form of a Julian date (last digit of the year followed by the day of the year, i.e., 23 May 1968 is written 8144). The next positions (not to exceed six) selected by the manufacturer may be either numbers or letters, or a combination of both.

BALANCE MARKER.–The balance marker is a red dot permanently branded into the sidewall of the tire immediately above the bead. It indicates the lightweight point of the tire and must be placed next to the balance marker on the inner tube when mounting.

CUT-LIMIT IDENTIFICATION.–The cut-limit dimension is expressed in thirty-seconds of an inch, and is rounded to the next smaller thirty-seconds of an inch increment when a fraction of a thirty-second inch is involved. It is molded in a minimum of two places equally spaced on each sidewall of the tire.

TREAD CONSTRUCTION.–Tires with fabric reinforced tread are marked FABRIC TREAD.

VENT MARKINGS.–Tube-type tires with inflation pressures greater than 100 psi and all tubeless tires must be suitably vented to relieve trapped air. Tube-type tires are vented in either of two ways. The first method uses air bleed ridges on the inside tire surface and grooves on the bead faces. The ridges and grooves channel to the outside the air trapped between the inner tube and the tire. The second method uses four or more vent holes that extend completely through each tire sidewall. They relieve both pocketed air and air that accumulates in the cord body by normal diffusion through the inner tube and tire. Tube-type tire vent holes are marked with an aluminum or white colored dot.

Tubeless tires have vent holes that penetrate from the outside of the tire sidewall to the outer plies of the cord body. They relieve air that accumulates in the cord body by normal diffusion through the tubeless tire liner and the tire carcass. Vent holes in tubeless tires are marked with a bright green dot.

NOTE: Tubeless tires must be marked TUBELESS.

In addition to the above markings, all tires are marked with the manufacturer's name or trademark, manufacturer's mold number, and country of manufacture (if other than USA).

RETREAD TIRE IDENTIFICATION.–The identification data required of the original tire manufacturer is required to remain on the tire and must be replaced by engraving or embossing if removed during retreading. In addition, the retread tire is required to be legibly marked and identified as follows: The letter "R" or "TR" followed by a numeral "1", "2", or "3", etc., to indicate the first, second, or third time the tire has been retreaded, Julian date of retread manufacture, and the name of the retread manufacturer and plant location.

When a retread tire has a cut repair extending into the carcass plies, a letter "c" is placed in the new rubber in the shoulder area directly adjacent to the cut repair.

STORAGE OF TIRES

The life of a tire is directly affected by storage conditions. Tires should be stored indoors in a dark, cool, dry room. It is necessary that they be protected from light (especially sunlight) to prevent checking. This may be accomplished by painting the storeroom windows. They must also be protected from excessive heat, strong air current, dirt, and dampness. Tires must not be allowed to come in contact with oils, greases, solvents, or other petroleum products that cause rubber to soften or deteriorate. The storeroom should not contain any kind of sparking electrical equipment that would produce ozone, nor any fluorescent lights.

Tires should be stored vertically in racks, according to size as shown in figure 9-10. The edges of the racks must be planed down or designed so that the tire tread does not rest on a sharp edge. Tires must never be stacked horizontally in piles. The issue of tires from the

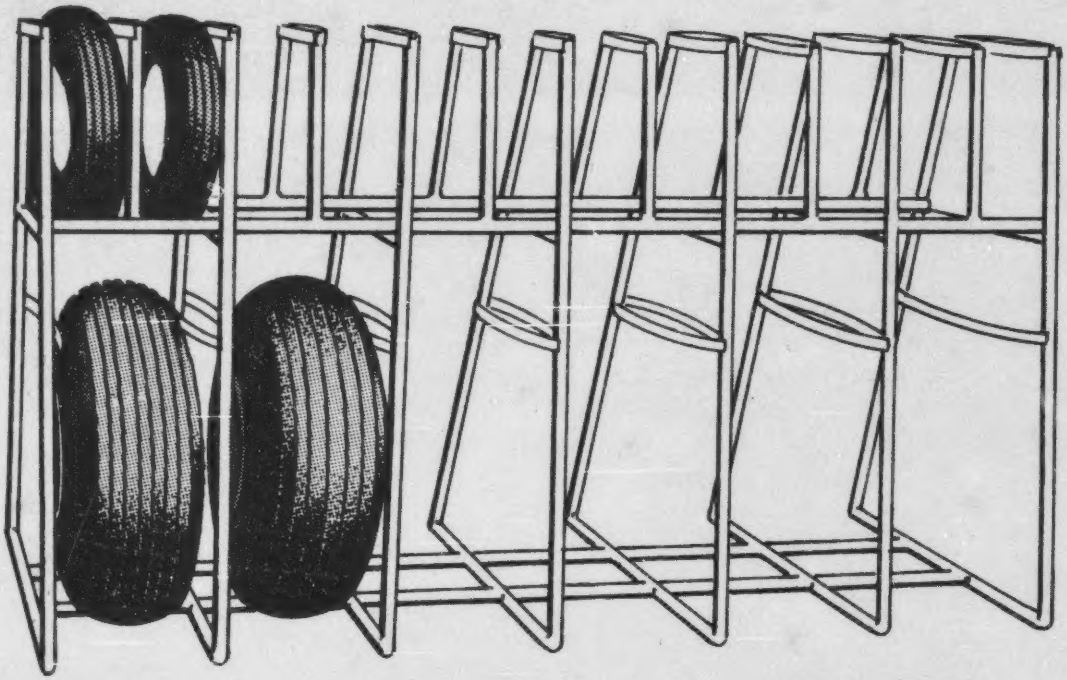


Figure 9-10.–Tire storage rack.

storeroom should be strictly on the basis of age from the date of manufacture so that the older tires will be used first, preventing the chance of deterioration of the older tires in stock.

INSPECTION AND MAINTENANCE OF TIRES

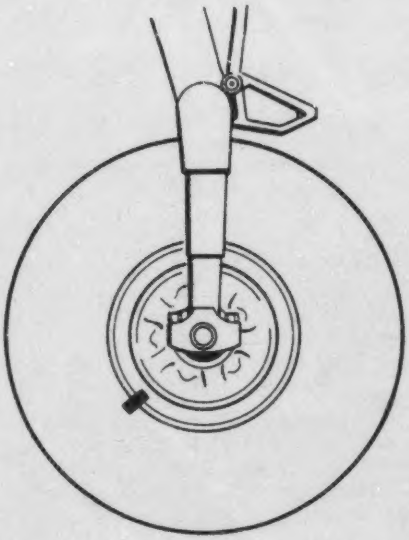
There are two types of inspections conducted on the tires; one is conducted with the tire mounted on the wheel, while the other is conducted with the tire dismounted.

Mounted Inspection

During the first preflight inspection each day, the tires must be inspected for correct pressure, tire slippage on the wheel (tube type tires), cuts, wear, and general condition. Tires must also be inspected before each flight for obvious damage that may have been caused during or after the previous flight.

Maintaining the correct inflation pressure in an aircraft tire is essential to obtain maximum safe service life. Military aircraft inner tubes and tubeless tire liners are made of natural rubber to satisfy extreme low temperature performance requirements. Natural rubber is a relatively poor air retainer. This accounts for the high daily inflation pressure loss and the need for frequent pressure checks. If this check discloses more than a normal loss of pressure, check the valve core for leakage by putting a small amount of saliva or water on the end of the valve and watch for bubbles. Replace the valve core if it is leaking. If no bubbles appear, it is an indication that the inner tube (or tire) has a leak. When a tire and wheel assembly shows repeated pressure loss exceeding 5 percent of the correct operating inflation pressure, it should be removed from the aircraft and sent to the IMA.

After making a pressure check, always replace the valve cap, insuring that it is screwed on fingertight. The cap prevents moisture, salt, oil, and dirt from entering the valve stem and damaging the valve core. It also acts as a secondary seal if a leak should develop in the valve core.



AM.409

Figure 9-11.—Tire slippage mark.

Tires which are equipped with inner tubes, and operate with less than 150 psi, and all helicopter tube type tires must utilize tire slippage marks. The slippage mark is a red stripe painted 1 inch wide and 2 inches long, extending equally across the tire sidewall and the wheel rim as illustrated in figure 9-11. Aircraft meeting the above requirements should be inspected for tire slippage on the rim after each flight. If the markings do not align within 1/4 inch, the wheel assembly must be replaced and the defective assembly forwarded to the IMA for repair. Failure to correct tire slippage may cause the valve stem to be ripped from the tube.

During the visual inspection of tires for cuts, wear, and general condition, any foreign objects such as stones, glass, metal, or other materials embedded in the tread should be removed. A common screwdriver or other blunt instrument may be used.

WARNING: When probing for foreign objects, extreme care must be used to prevent the probe from penetrating deeper into the tire. Objects being pried from the tire frequently are ejected suddenly and with considerable force. Therefore, to avoid eye injury, safety glasses or a face shield must be worn. (A gloved hand over the object may be used to deflect it.)

Tires must be removed from the aircraft when the tread pattern is worn to less than 1/32-inch, at any spot, or to the limits of the tread wear indicators; if the tire's sidewall cord body fabric is exposed; or if the tread cuts exceed the depth specified on the sidewall of the tire or in the Technical Manual, Aircraft Tires and Tubes, NavAir 04-10-506. Figure 9-12 shows the method for measuring cuts, cracks, and holes.

Dismounted Inspection

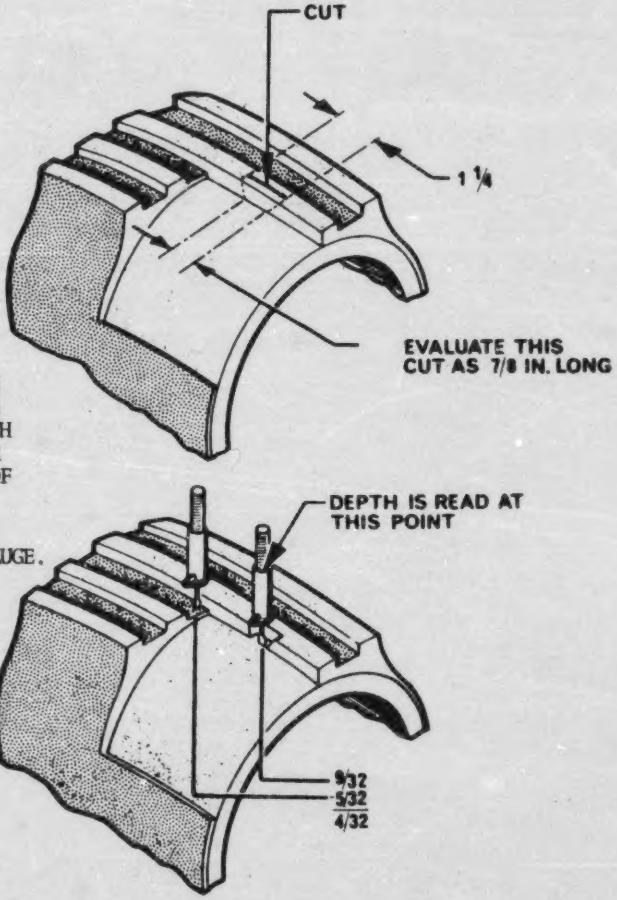
Whenever a tire has been subjected to a hard landing or has hit an obstacle, it should be dismounted for a complete inspection to determine if any internal injuries have occurred. The tire beads should be spread and the inside of the tire inspected with the aid of a light. If the lining has been damaged or there are other internal injuries, the tire should be removed from service. Check the entire bead area and the area just above the bead for evidence of rim chafing and damage. Check the wheel for damage which may damage the tire after it is mounted.

DISMOUNTING AND MOUNTING

During mounting and dismounting of tires, safety is paramount. Compressed air and nitrogen present a safety hazard, if the operator is not aware of the proper operation of the inflation equipment and the characteristics of the inflation medium. It is also very important to know the wheel type and be familiar with the manufacturers recommended procedure before attempting to dismount a tire. For specific precautions concerning a particular installation, always consult the applicable Maintenance Instructions Manual.

Dismounting

The AMS working in the tire shop should recheck tires for complete deflation prior to disassembling the wheel and breaking the bead of the tire. Breaking the bead means separating


CUT
1 ¼
EVALUATE THIS CUT AS 7/8 IN. LONG
DEPTH IS READ AT THIS POINT
9/32
5/32
4/32

1. MEASURE REMAINING TREAD DEPTH.
2. MEASURE DEPTH OF CUT.
3. SUBTRACT THE DEPTH OF THE REMAINING TREAD FROM THE DEPTH OF THE CUT. THE RESULT IS THE MEASUREMENT TO BE COMPARED WITH THE LIMITS SPECIFIED IN NAVAIR 04-10-506 OR ON THE SIDEWALL OF THE TIRE AS APPLICABLE.
4. ALL MEASUREMENTS SHOULD BE MEASURED WITH A TREAD DEPTH GAUGE.

FSN 5210-357-5951

AM.1218

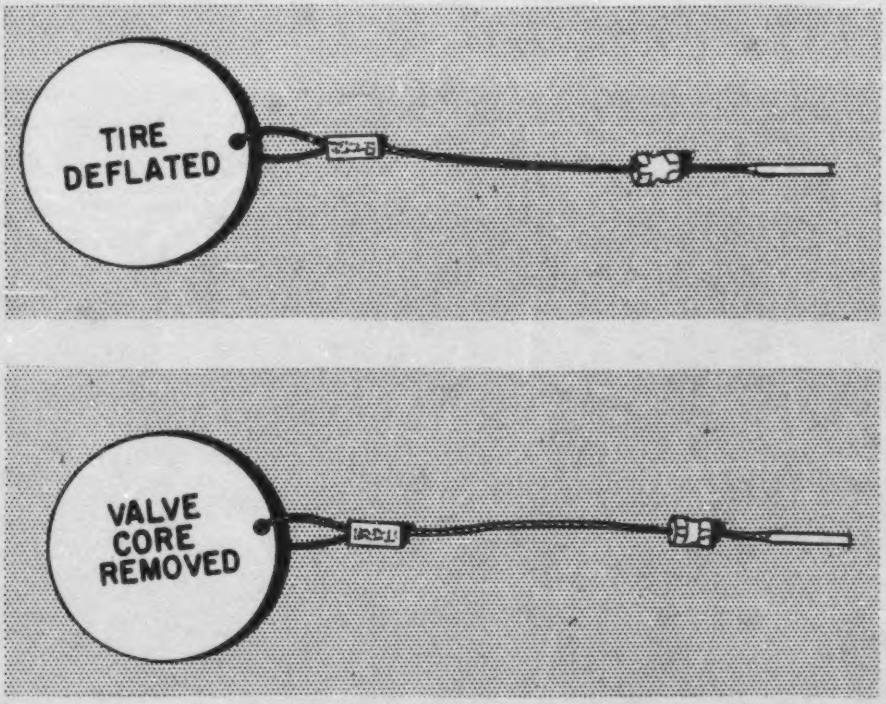
Figure 9-12.–Method of measuring depth and length of cuts, cracks, and holes.

the bead of the tire from the wheel flange. When a tire has been completely deflated and set aside to await the bead-breaking operation, the valve core should be removed and a deflated tire flag (as shown in fig. 9-13) installed on the valve stem. The tire flags should be so constructed as not to be installable unless the valve core has been removed.

BREAKING THE BEAD.–The use of proper equipment for breaking the bead of the tire away from the wheel flange will save materials and manhours. Aircraft tires, inner tubes, and wheels can be damaged beyond repair by improper mounting and dismounting equipment and procedures. The equipment in figure 9-14 is recommended by NavAir 04-10-506. Other commercially available or locally fabricated equipment which uses either a hydraulically actuated cylinder or a mechanically actuated device may also be used, provided the equipment will not damage the tires or wheels. The bead-breaking equipment shown in figure 9-14 is available in two models. Model Lee-1 is designed for installation and service in shore based facilities and Model Lee-IX is an explosion-proof version of the Lee-1 intended for shipboard use.

The following is a step-by-step procedure in the proper operation of the Model Lee-1 equipment.

1. Insure the tire is completely deflated.



AM.410

Figure 9-13.—Deflated tire flag.

2. Determine the type and size of wheel to be dismounted and assemble the proper parts on the drive shaft.

3. Push the outer centering rollers toward the front of the machine and roll the wheel (positioned with the lockring side facing outward for demountable flange wheels) on the outer centering rollers. Using the up and down pushbuttons, raise or lower the drive shaft to the proper height for the wheel being dismounted, and push the wheel onto the drive shaft. If an open rimmed tire assembly is being dismounted omit step 4 and proceed to step 5.

4. Insert the locking bar and turn about 90 degrees counterclockwise. Mount the wheel cone on the locking bar and insert the locking pin.

5. Push the air valve switch to the right; this will clamp the wheel on the drive shaft.

6. Using the UP pushbutton, raise the center of the wheel to line up with the center of the bead-breaking disc.

7. Rotate the tire by pushing the tire rotating toggle to the right. Position the front beadbreaking disc against the outside bead of the wheel flange. If necessary, adjust the position of the hydraulic pump assembly by loosening the position lock pin and sliding the pump to the proper position. After turning the pump release valve clockwise as far as it will go, apply hydraulic pressure against the bead by pumping the handle as illustrated in figure 9-15. Use the guide handle to properly position the disc. Push the bead back far enough to allow the removal of the lockring or loose flange.

8. Remove the lockring and loose flange. If necessary use the bead shoes (fig. 9-16) to hold

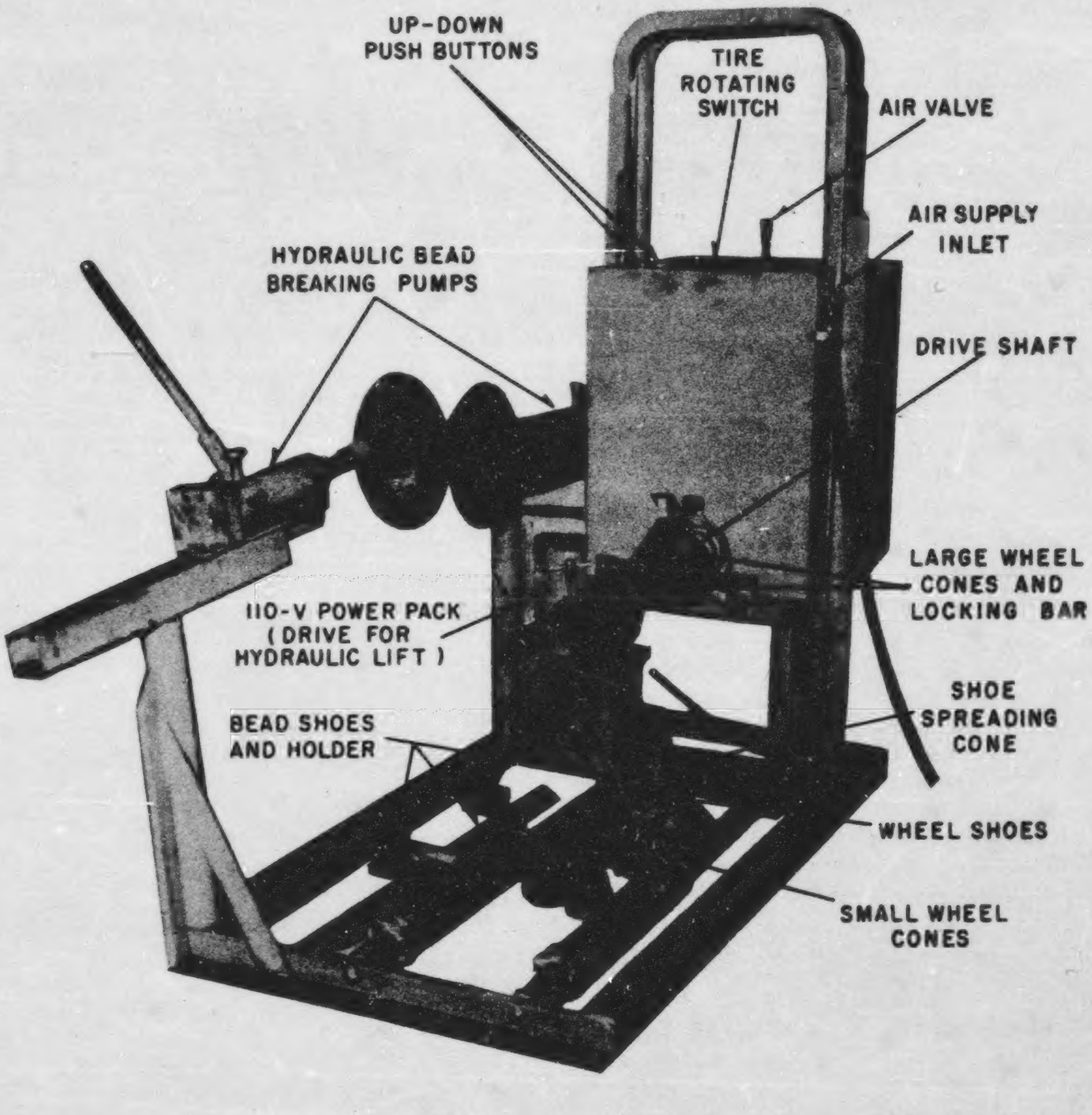
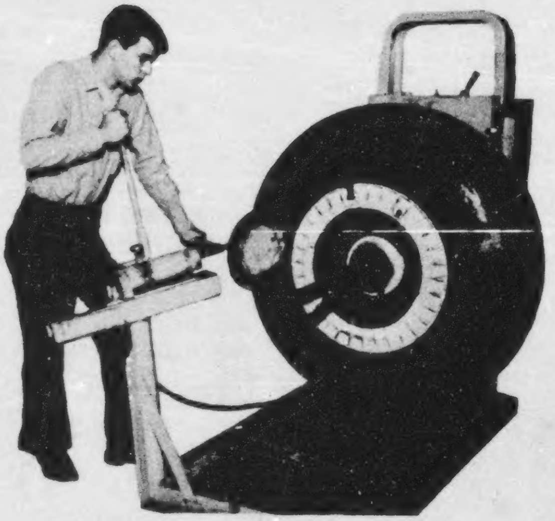


Figure 9-14.—Aircraft wheel holder and tire bead breaking machine.

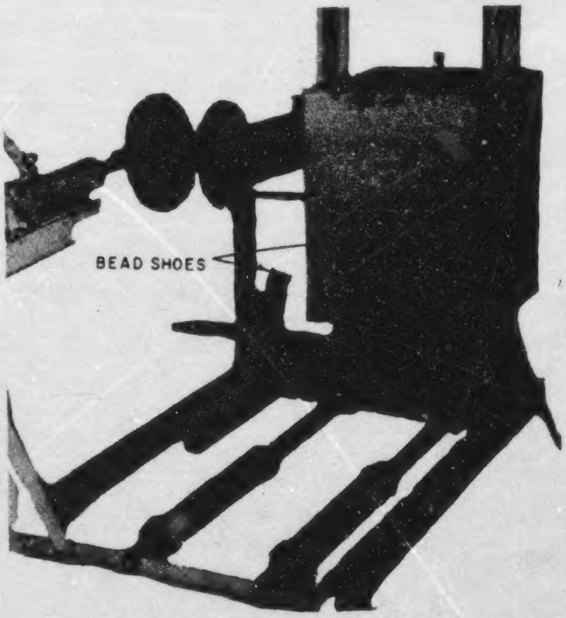
the bead back while removing the lockring. Release and retract the front bead-breaking disc by turning the release valve counterclockwise.

9. Repeat the bead-breaking operation against the rear surface of the tire, using the rear bead breaking assembly.



AM.412

Figure 9-15.—Using bead-breaking pump.



AM.413

Figure 9-16.—Shaft arranged to hold tire bead while removing lockring.

10. On all divided (split) type wheels, after the beads are broken, remove all nuts and bolts while the wheel assembly is still mounted on the machine.

Dismounting Divided (Split) Wheels.—Tire bead is broken away from the wheel and nuts and bolts are removed as previously described.

NOTE: If the tire is a tube type, remove the hex nut (if any) and push the valve away from the seated position to prevent damage to the inner tube valve attachment when breaking the tire bead loose. Remove the wheel assembly from the tire. If the tire is a tubeless type, remove the wheel seal carefully from the wheel half and place it on a clean surface. Wheel seals in good condition may be reused if replacement seals are not available. If the tire is a tube type, remove the inner tube. Inner tubes can be reused if in good condition, and if less than 5 years old.

Dismounting Demountable Flange Wheels.—Tire bead is broken away from the wheel as previously described.

NOTE: If the tire is a tube type, remove the hex nut (if any) and push the valve away from the seated position to prevent damage to the inner tube valve attachment when breaking the bead.

If trouble is encountered in removing the flange while the wheel is mounted on the bead breaking machine, remove the tire from the machine. Lay the tire and wheel assembly flat with the demountable flange side up. Drive the demountable flange down by tapping with a rubber, plastic, or rawhide-faced mallet, far enough to enable removal of the locking ring.

CAUTION: Extreme care must be taken when breaking the beads loose and when removing the lockring on some demountable flange wheels. The toe of the demountable flange on these wheels extends very close to the tube valve stem. Excessive travel of the demountable flange, when removing the lockring, or of the tire bead, when breaking the beads loose, will damage the rubber base of the inner tube valve.

If the tire is a tubeless type, remove the wheel seal carefully and place it on a clean surface. Wheel seals in satisfactory condition may be reused if replacement seals are not available. Turn the tire and wheel assembly over, and lift the wheel out of the tire. If the tire is a tube type, remove the inner tube. Inner tubes may be reused if in a satisfactory condition. Remember to keep the wheel flange and locking ring together as a unit to avoid possible mismatch during remounting.

Mounting

Prior to mounting a tire on a wheel, the AMS must inspect the tire for condition and insure the inside of the tire is free of foreign materials. The inner tube must be inspected for bead chafing, thinning, folding, surface checking, heat damage, fabric liner separation, valve pad separation, damaged valves, leaks, and other signs of deterioration. The wheel assembly is inspected in accordance with current directives.

Mounting of divided (split) and demountable flange wheel assemblies is covered here to acquaint the AMS with the basic procedures. For specific information in regard to a given tire assembly, consult the applicable Maintenance Instructions Manual.

MOUNTING DIVIDED (SPLIT) WHEELS.–All wheel halves should be matched by year and month of manufacture as closely as possible. Wheel assemblies received from overhaul having matching overhaul dates on both rims should be maintained as matched assemblies. In the event a wheel assembly is received or made up of wheel halves having different overhaul dates, the wheel overhaul should be based upon the earlier date. All wheels should fit together easily without forcing.

When mounting a tube type tire, dust the tube with talcum powder and insert the tube in the tire. The tire should be positioned so that the balance marker on the tube is located next to the balance marker of the tire.

NOTE: The balance marker on an inner tube is a stripe approximately 1/2 inch wide and 2 inches long in contrasting colors. It is located on the valve side of the tube. The balance mark on a tire is a red dot approximately 1/2 inch in diameter. It is located on the sidewall near the bead.

Inflate the tube until it is rounded out and place the valve-hole half of the wheel into position in the tire. Push the valve stem through the hole. Insert the other half of the wheel and align the boltholes.

NOTE: All bolts must be magnetic particle inspected to insure they are not defective. Install four bolts, nuts, and washers 90 degrees apart. Start the bolts by hand, and draw up evenly until the wheel halves seat. Install the remaining bolts, nuts, and washers. Tighten the bolts in a crisscross order to prevent distorting the wheel or damaging the inserts. A pneumatic powered impact wrench may be used, provided the torque obtained does not exceed 25 percent of the specified final torque required for the wheel. Use a currently calibrated torque wrench and tighten each bolt in increments of 25 percent of the specified torque value in a crisscross order until the total torque value required for each bolt in the wheel has been reached.

NOTE: When "Lubtork" is specified on the wheel half, coat all treads and bearing surfaces of boltheads with MIL-T-5544 antiseize compound. "Lubtork" must not be used on magnesium wheels. For magnesium wheels use MIL-G-21164 lubricant. All excessive lubricant should be removed.

Prior to mounting tubeless tires, check the tire sidewall for the word "Tubeless." Treat all tires not so marked as tube type tires. When mounting tubeless tires, install the valve stem (valve core removed) in the wheel assembly. Removing the valve core prevents unseating of the wheel seal by pressure built up when the tire is installed. Insert one wheel half in the tire and position the tire so that the balance marker on the tire is located at the valve stem. Install the wheel seal, which has been lubricated with a light coat of MIL-G-4343 lubricant, on the outer wheel half. Install the other wheel half and align the boltholes. Install bolts, washers, and nuts in the same manner as explained earlier for the wheel assembly containing inner tubes.

MOUNTING DEMOUNTABLE FLANGE WHEELS.–When mounting a tube type tire on a demountable flange wheel, the inner tube is prepared and inserted in the tire in the same manner as on a split or divided wheel. The wheel is then positioned on a flat surface with the fixed flange down. Push the tire on the wheel assembly as far as it will go, guiding the valve stem into the valve slot with the fingers. Install the demountable flange on the wheel, and secure the locking ring in accordance with the assembly instructions required by the applicable wheel manual.

When mounting a tubeless type tire on a demountable flange wheel, install the valve stem (valve core removed) in the wheel assembly. Removing the valve core prevents unseating the wheel seal by pressure built up when the tire is installed. The wheel seal is lubricated with the same lubricant and in the same manner as previously mentioned for split or divided wheel assemblies using tubeless tires. The wheel seal is installed on the flange sealing surface. Install the demountable flange on the wheel, and secure the locking ring in accordance with the assembly instructions required by the applicable wheel manual.

Tire Inflation

The AMS is required to have a thorough knowledge of servicing tires. The equipment used and procedures for inflating tires are covered in chapter 12. The actual inflation medium is covered in the following section.

In the past, aircraft tires have been inflated with clean dry air. The trend now is from a clean dry air source to nitrogen. Nitrogen, (BB-N-411B) type 1 class 1, is preferred because oxygen in the air reacts with the tire rubber at high temperatures and pressure. This causes deterioration, reduces the tire life, and constitutes a blowout hazard. If circumstances dictate that air rather than nitrogen must be used, the air line from the compressor must be equipped with a trap to remove all water and oil.

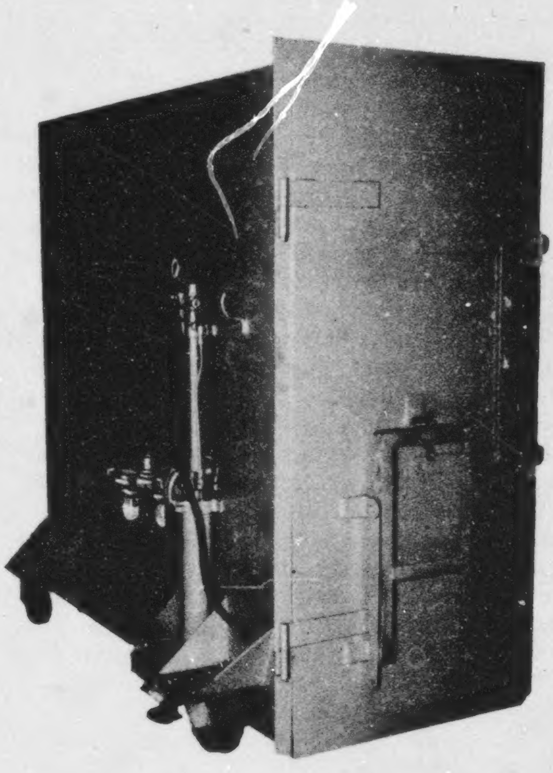
All high-pressure inflation sources must be equipped with reducing valves that limit the line pressure to 600 psi or 50 percent above the maximum tire inflation pressure, whichever is the lesser.

Slippage marks must be painted on all newly mounted helicopter tube type tires and other tube type tires which are inflated to 150 psi or less.

A loss of pressure, not to exceed 5 percent, will be experienced during the first 24 hours after initial inflation of a new tire. This is attributed to normal tire stretch and the tire pressure should be adjusted accordingly.

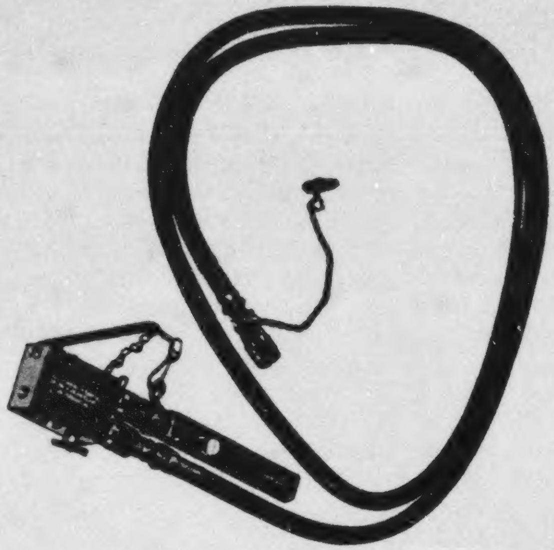
INFLATION OF NEW TIRES.–After the buildup of a tire and when the tire is ready to be inflated, it is placed within a safety cage for inflation. A typical safety cage is shown in figure 9-17. The method of inflation used depends on whether a tube or tubeless type tire is being inflated.

Inflation of Tube Type Tires.–Remove the valve core and place the wheel assembly in the



AM.414

Figure 9-17.–Safety cage for inflation of tires.



AM.1219

Figure 9-18.–Remote inflator assembly.

safety cage. Attach a remote tire inflation gage assembly (figure 9-18) to the valve stem. Check to make sure the inner tube is not being pinched between the tire bead and the wheel flange. Check demountable flange wheels to make sure the demountable flange and locking ring are seated properly. Secure the safety cage door and inflate the tire to its maximum operating pressure to seat the tire beads against the rim flanges. Deflate the tire, install the valve core, and reinflate the tire to its maximum operation pressure. Allow the tire to remain at this pressure for a minimum of 10 minutes. At the end of this 10-minute period, there should be no detectable pressure loss.

If no pressure loss is detected, the tire pressure is reduced to 50 percent of the maximum operating pressure or 100 psi, whichever is the lesser. The tire/wheel assembly is then removed from the safety cage, a valve cap installed, and the assembly stored in a rack, ready for issue.

If there is a significant pressure loss, the tire pressure is reduced to 50 percent of the maximum operating pressure, the assembly removed from the safety cage, and the cause of the leak determined. If a slow leak is detected, the air retention test should be extended to 24 hours. The tire should not be issued until remedial action is taken if the leakage exceeds 5 percent.

Inflation of Tubeless Tires.–Tubeless tires are inflated in the same manner as previously explained for tube type tires except it is not necessary to inflate tubeless tires with the valve core removed.

RETREADING AND REPAIR

The Navy considers all aircraft tires to be potentially retreadable. Used aircraft tires should not be discarded or scrapped until it has been definitely determined that they are unfit for further use.

All tires removed from aircraft should have the injuries marked with a wax crayon. The tire is then turned in to the Intermediate Maintenance Activity (IMA) for screening. The IMA will determine if the tire is serviceable or nonserviceable and take the necessary action.

Serviceable Tires

Serviceable tires are those judged suitable for continued service use by the tire shop personnel. They should be retained in service until the remaining tread at any spot is 1/32 inch thick or to the limits of the tread wear indicators. Defects permitted are cut limits contained on the tire sidewall or as listed in the technical manual, Aircraft Tires and Tubes, NavAir 04-10-506. Cuts are permitted in the sidewall provided they do not penetrate to the cord body fabric.

Nonserviceable Tires

Nonserviceable tires may be nonretreadable or retreadable.

NONRETREADABLE.–Nonretreadable tires are coded for condemnation and forwarded to the nearest Property Disposal Officer via the local Supply Department. The following inspection criteria must be used by the tire shop personnel to determine those tires that are nonretreadable:

1. Blowouts.
2. Punctures extending through the entire carcass measuring more than 1/4 inch in diameter/length on the outside and more than 1/8 inch in diameter/length on the inside.
3. Loose, frayed, or broken cords evident on the inner tire surface.
4. Cord body fabric damage, visible to the naked eye without the use of mechanical devices.

NOTE: Exposure of cords on fabric reinforced tread tires (which is imprinted on the tire sidewall) is permissible.

5. Kinked, broken, or exposed wire beads.
6. Tread separation and bulges exceeding 1 inch.
7. Tires saturated with rubber deteriorating liquids.
8. Tires exposed to excessive heat.

RETREADABLE.–All tires removed from service which are not condemned are potentially repairable and must be returned to the Supply Department for retreading. The number of retreads a carcass may receive will be based solely on carcass integrity as determined by the applicable inspection criteria.

PREVENTIVE MAINTENANCE

Debris on the runways and parking areas causes tire failures and results in many tires being removed long before giving full life, as a result of cuts. It is therefore important that such areas be kept clean at all times.

When ground handling an aircraft, do not pivot with one wheel locked or turn sharply at slow speeds, as this not only scuffs the tread off, but also causes internal separation of the cords. Always be sure the aircraft is moving before attempting a turn. This allows the tire to roll instead of scrape.

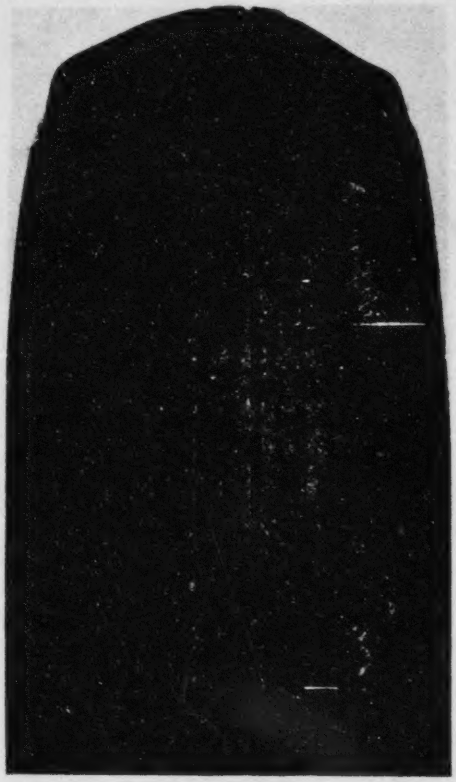
Particular care should be observed in preventing oil, grease, hydraulic fluid, or other harmful materials from coming in contact with the tires. During maintenance, when there is a chance that harmful materials may come in contact with the tires, they should be protected by covers. To clean tires which have come in contact with oil, grease, or other harmful materials, use a brush or cloth saturated in a soap and water solution. Rinse well with tap water.

Uneven Tread Wear

If a tire shows signs of uneven or excessive tread wear, the cause should be investigated and the condition remedied before the tire is ruined.

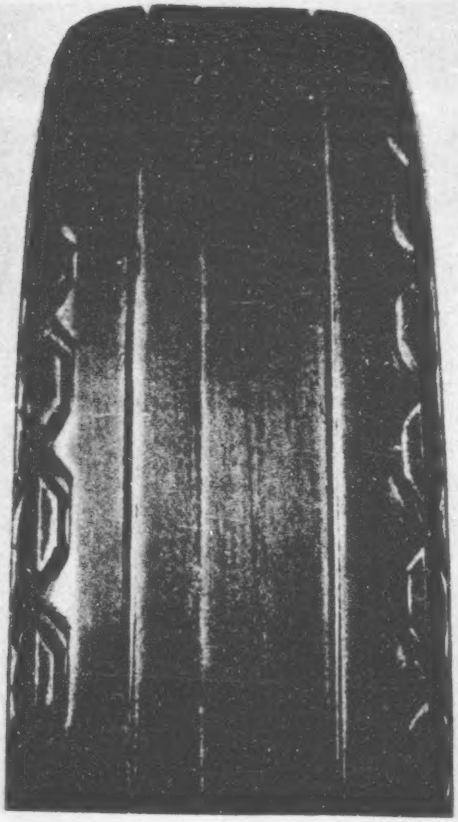
UNDERINFLATION.–Underinflation causes the tire to wear rapidly and unevenly at the outer edges of the tread as shown in figure 9-19. An underinflated tire develops higher temperatures during use than a properly inflated tire and this can result in tread separation or blowout type failure.

OVERINFLATION.–Overinflation reduces the tread contact area causing the tire to wear faster in the center as shown in figure 9-20.

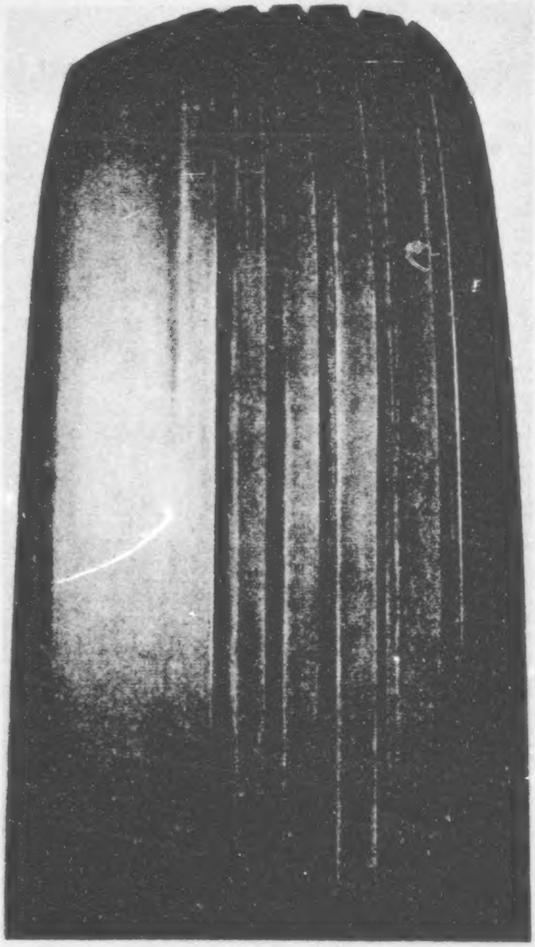


AM.1220

Figure 9-19.–Rapid tread wear caused by underinflation.



AM.1221
Figure 9-20.–Rapid tread wear caused by overinflation.



AM.1222
Figure 9-21.–Rapid tread wear caused by misalignment.

Overinflation increases the possibility of damage to the cord on impact with foreign objects and arresting cables on the runway or flight deck.

MISALIGNMENT.–Figure 9-21 shows rapid and uneven tire wear caused by incorrect camber or toe-in. The wheel alignment should be corrected in accordance with the applicable aircraft manual to avoid further wear and mechanical problems.

BALANCE.–Correct balance of the tire, tube, and wheel assembly is important. A heavy spot on an aircraft tire causes that spot to always hit the ground first upon landing, resulting in excessive wear at the one spot and an early failure at that part of the tire. A severe case of imbalance causes excessive vibration during takeoff and landing. This makes handling of the aircraft difficult.

Nylon Flat Spotting

If the aircraft stands in one place under a heavy static load for several days, local stretching may cause an out-of-round condition with the resultant thumping during takeoff and landing.

Dual Installations

On dual-wheel installations, tire should be matched in accordance with dimensions indicated in table 9-1. Tires vary somewhat in size between manufacturers and can vary a great deal after being used. When two tires are not matched, the larger one supports most or all of the load. Since one tire is not designed to carry this increase in load, a failure may result.

Table 9-1.—Tolerances for diameters of paired tires in dual installations.

Tire outside diameter	Maximum difference in outside diameters
Less than 18 inches	1/8 inch
18 to 24 inches	1/4 inch
25 to 32 inches	5/16 inch
33 to 40 inches	3/8 inch
41 to 48 inches	7/16 inch
49 to 55 inches	1/2 inch
56 to 65 inches	9/16 inch
More than 65 inches	5/8 inch

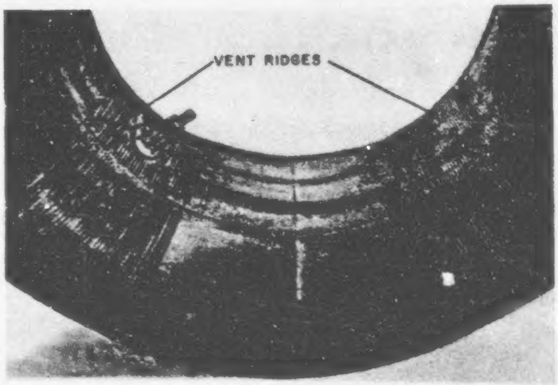
INNER TUBES

The purpose of the inner tube is to hold the air in the tire. Tubes are identified by the type and size of the tire in which they are to be used.

IDENTIFICATION

Tube types are designated the same as for the corresponding tires in which they are to be used. For example, a type I tube is designed for use in a type I tire. Tube size is the size of the tire the tube is designed to fit.

Inner tubes required to operate at 100 psi or higher inflation pressures are usually reinforced with a ply of nylon cord fabric around the inside circumference. The reinforcement extends a minimum of 1/2 inch beyond that portion of the tube which contracts the rim.



AM.1223
Figure 9-22.—Inner tube vent ridges.

Type III inner tubes used at inflation pressures above 100 psi, and all type VII inner tubes, have radial vent ridges molded on the surface, as shown in figure 9-22, to relieve air trapped between the casings and the inner tube during inflation.

Inner tube valves are designed to fit specific wheel rims. However, special valve bending configurations or extensions to provide access to the valve stem when servicing the tire may be required.

STORAGE

Tubes should be stored under the same conditions as that outlined for tires. New tubes should be stored in their original containers. Used tubes should be partially inflated (to avoid creasing in storage), dusted with talc (to prevent sticking) and stored in the same manner as tires. Each tube should be plainly marked to identify contents, size, type, cure date, and stock number. Under no circumstances should inner tubes be hung over nails or hooks.

INSPECTION

Inner tubes should be inspected and classified as serviceable or nonserviceable. Usually, leaks due to punctures, breaks in the tire, cuts, and the like, can be detected by the eye, but small leaks require a water check. Complete submersion in water is the best way to locate small leaks. If the tube is too large to be submerged, spread water over the entire surface and examine carefully for air bubbles. The valve stem and valve base should be swished around to break any temporary seals. The tube should be checked for bent or broken valve stems, also for stems with damaged threads.

Serviceable Tubes

Inner tubes should be classified as serviceable if they are found to be free of leaks and other defects when inflated with a minimum of nitrogen required to round out the tube and then immersed in water.

Nonserviceable Tubes

Nonserviceable tubes may be repairable or nonrepairable.

REPAIRABLE.–Nonserviceable tubes with the following defects should be classified as repairable:

1. Bent, chafed, or damaged metal valve threads.
2. Replaceable leaking valve cores.

NONREPAIRABLE.–Nonserviceable tubes with the following defects should be classified as nonrepairable:

1. Any tear, cut, or puncture which completely penetrates the tube.
2. Fabric reinforced tubes with blisters greater than 1/2 inch in diameter in the reinforced area.
3. Chafed or pinched areas caused by beads or tire breaks.
4. Valve stems pulled out of fabric base type tubes.
5. Deterioration or thinning due to brake heat.
6. Folds or creases.
7. Severe surface cracking.
8. No balance marker.

CHAPTER 10

TUBING, FLEXIBLE HOSE, AND CLAMPS

In this chapter we will discuss rigid tubing, flexible hose, and the line clamps that are used to support and bond rigid tubing to the aircraft structure. Modern day aircraft have hundreds of feet of tubing and flexible hose running throughout the wings and fuselage. The AMS is not responsible for maintaining the fluid systems in Navy aircraft, but in many instances he is called upon to assist the AMH and AME in maintaining their respective systems. Therefore a knowledge of the materials, tools, equipment required, and the proper procedures to follow in fabricating and installing tubing, flexible hose, and line clamps is necessary.

Many lives have been lost in aircraft accidents caused by fluid line and/or fitting failure. The following quotes are typical of some found in aircraft accident reports.

"Hydraulic fitting cracked. Probable cause, overtorque of nut during line installation following system maintenance."

"Hole in utility system pressure line. Investigation revealed chafing of pressure line by port aileron control cable. Cause, support clamp not reinstalled after hydraulic pressure line was replaced following system maintenance, thus allowing the pressure line to contact the control cable."

"Flexible hose parted at end fitting. Cause, incorrect end fittings installed during fabrication of replacement hose assembly by maintenance personnel."

NOTE: The quotes listed above point out just a few different maintenance errors that have caused or are suspected of causing aircraft accidents.

FLUID LINE IDENTIFICATION

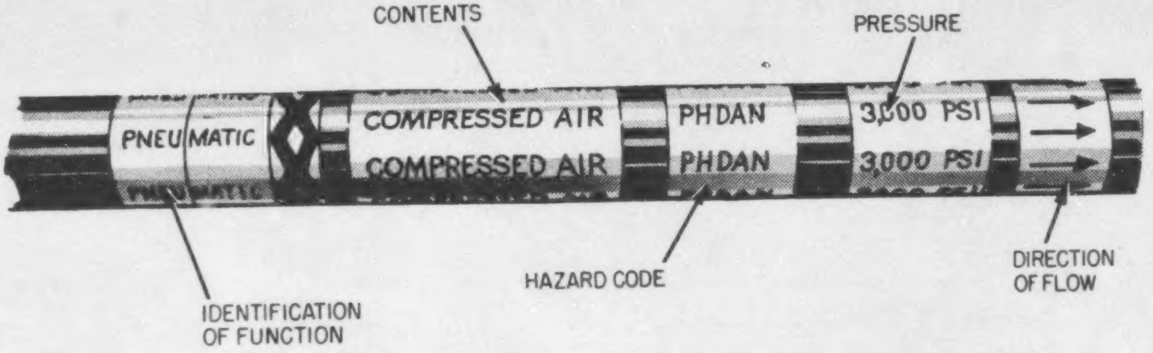
Each fluid line in the aircraft is identified by bands of paint or strips of tape around the line near each fitting. These identifying media are applied at least once in each compartment. Various other information is also applied to the lines.

In most instances, lines are marked by the use of tape or decals. On lines 4 inches and larger in diameter, lines in an oily environment, hot lines, and on some cold lines, tages may be used in place of tape or decals.

NOTE: On lines in engine compartments, where there is the possibility of tapes, decals, or tags being drawn into the engine induction system, the information can be applied as follows: Type or print (ballpoint pen) the information on white paper or decal and place it in position on the tubing. Apply a length of clear, heat-shrinkable rubber tubing, MIL-R-46846 type V, over the area, 1/2-inch longer than the label.

Identification tape codes indicate the function, contents, hazards, direction of flow, and pressure in the fluid line. These tapes are applied in accordance with MIL-STD-1247. This Military Standard was issued in order to standardize fluid line identification throughout the Department of Defense. Figure 10-1 illustrates the method of applying these tapes as specified by this standard.

The function of a line is identified by use of a tape, approximately 1 inch wide, upon which word(s), color(s), and geometric symbols are printed. Functional identification markings, as provided in MIL-STD-1247, are the subject of international standardization agreement. Three-



AM.66

Figure 10-1.–Fluid line identification application.

fourths of the total width on the left side of the tape has a code color or colors which indicate one function only per color or colors. The function of the line is printed in English across the colored portion of the tape; therefore, even a non English-speaking person can troubleshoot or maintain the aircraft if he knows the code but cannot read English. The right-hand one-fourth of the functional identification tape contains a geometric symbol which is different for every function. This is to insure that all technicians, whether English speaking or not, who may be colorblind may still be able to positively identify the line function by means of the geometric design rather than by the color(s) or word(s). Figure 10-2 is a listing, in tabular form, of functions and their associated identification media as used on the tapes.

The identification-of-hazards tape shows the hazard associated with the contents of the line. Tapes used to show hazards are approximately one-half inch wide, with the abbreviation of the hazard contained in the line printed across the tape. There are four general classes of hazards found in connection with fluid lines. These hazards are outlined in the following paragraphs.

Flammable material (FLAM). The hazard marking "FLAM" is used to identify all materials known ordinarily as flammables or combustibles.

Toxic and poisonous materials (TOXIC). A line identified by the word "TOXIC" contains materials which are extremely hazardous to life or health.

Anesthetics and harmful materials (AAHM). All materials productive of anesthetic vapors and all liquid chemicals and compounds hazardous to life and property, but not normally productive of dangerous quantities of fumes, or vapors, are in this category.

Physically dangerous materials (PHDAN). A line which carries material which is not dangerous with in itself, but which is asphyxiating in confined areas or which is generally handled in a dangerous physical state of pressure or temperature is identified by the marking "PHDAN."

Table 10-1 lists some of the fluids with which the AMS may be required to work and the hazards associated with each.

RIGID TUBING

Rigid tubing assemblies are made up mainly of aluminum alloy or stainless steel tubing. However, copper tubing is used in certain parts of some oxygen systems.

Two aluminum alloys are in common use–alloy 5052 may be used for lines carrying pressures up to 1,500 psi and alloy 6061 for pressures up to 3,000 psi.

FUNCTION	COLOR	SYMBOL
Fuel	Red	✦
Rocket Oxidizer	Green, Gray	☽
Rocket Fuel	Red, Gray	✦☽
Water Injection	Red, Gray, Red	∨
Lubrication	Yellow	▪▪
Hydraulic	Blue, Yellow	●
Solvent	Blue, Brown	≡
Pneumatic	Orange, Blue	X
Instrument air	Orange, Gray	⟩
Coolant	Blue	∼
Breathing Oxygen	Green	▬
Air Conditioning	Brown, Gray	⁙
Monopropellant	Yellow, Orange	T
Fire Protection	Brown	◆
De-Icing	Gray	▲▲
Rocket Catalyst	Yellow, Green	Ⅲ
Compressed gas	Orange	╱
Electrical Conduit	Brown, Orange	⚡
Inerting	Orange, Green	✚✚

AM.67

Figure 10-2.—Functional identification tape data.

As a general rule, exposed lines and lines subject to abrasion, intense heat, or extremely high pressures are made of stainless steel.

Flexible hose is generally used in connection with moving parts or where a line is subject to considerable vibration.

TUBING SIZES

The tubing used in the manufacture of rigid tubing assemblies is sized by outside diameter (OD) and wall thickness. Outside diameter sizes are in sixteenth-inch increments, the number of the tube indicating its size in sixteenths of an inch. Thus, No. 6 tubing is 6/16 or 3/8 inch; No. 8 tubing is 8/16 or 1/2; etc. Wall thickness is specified in thousandths of an inch.

Replacement tubing assemblies should be fabricated from the same type materials as the original part. Most aircraft Maintenance Instructions Manuals contain a table of acceptable substitutes which lists the original material and wall thickness and substitutes with wall thicknesses for each.

TUBE FITTINGS

Fittings for tube connections are made of aluminum alloy, steel, and corrosion-resistant steel (CRES). Fittings are made in many shapes

Table 10-1.—Hazards associated with various fluids.

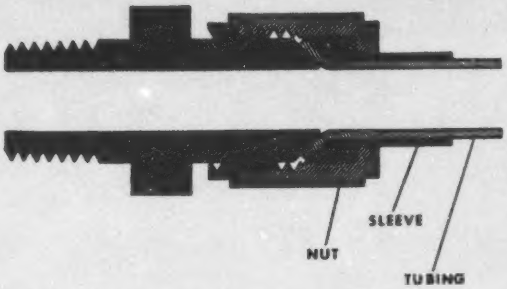
Contents	Hazard
Air (under pressure)	PHDAN
Alcohol	FLAM
Carbon dioxide	PHDAN
Freon	PHDAN
Gaseous oxygen	PHDAN
Liquid nitrogen	PHDAN
Liquid oxygen	PHDAN
LPG (liquid petroleum gas)	FLAM
Nitrogen gas	PHDAN
Oils and greases	FLAM
JP-5.	FLAM
Trichlorethylene	AAHM

and forms, each designed to fulfill certain requirements. The following paragraphs cover two common styles of tube fittings—the flared (AN) type and the flareless (MS) type. Also covered here is the metal lip-seal fitting, which is being used on the A-7 and A-4 aircraft.

Flared-Tube Fittings (AN)

The flared-tube fitting shown in figure 10-3 consists of a sleeve and a nut. The sleeve fits directly over the tube, and one end is countersunk at the same angle as the tubing flare. The nut fits over the sleeve, and when tightened, draws the sleeve and tubing flare tightly against the male fitting (connector) to form the seal. The male fitting has a cone-shaped surface with the same angle as the inside of the flare. The sleeve supports the tube so that vibration does not concentrate at the edge of the flare, and distributes the stresses over a wider area for added strength.

Flared-tube fittings are identified by their color. Aluminum alloy fittings are blue and steel fittings are black.



AM.68

Figure 10-3.—Flared-tube fitting.

Flareless-Tube Fittings (MS)

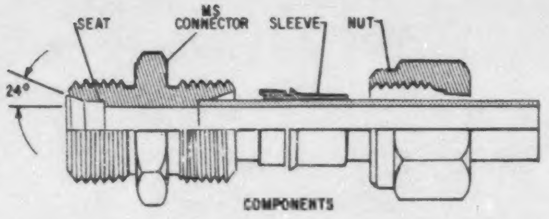
The flareless-tube fitting shown in figure 10-4 consists of a sleeve and a nut. Notice that the tubing is not flared. (In order to effect a seal between the tubing and the sleeve, an operation called presetting is performed which is discussed later in this chapter). The connector has a counterbore, a portion of which is beveled 24 degrees. The seat in the connector forms a stop for the tube, and the beveled area causes the sleeve to seal the connection as the nut is tightened.

There are two types of flareless-tube fittings in current use. The newer most widely used type consists of a long sleeve (MS21922) and short nut. (MS21921). The older type consists of a short sleeve (MS21918) and a long nut (MS21917).

Flareless-tube fittings are made of aluminum and steel. The aluminum fittings are identified, visually, by their green and yellow color, which is caused from the anodizing treatment. Steel fittings are cadmium plated, which makes their colors a silvery-white.

Metal Lip-Seal Fittings

Metal lip-seal fittings (unions, reducers, and plugs) are utilized throughout most brazed tubing type systems. Figure 10-5 illustrates a



AM.69

Figure 10-4.—Flareless-tube fittings.

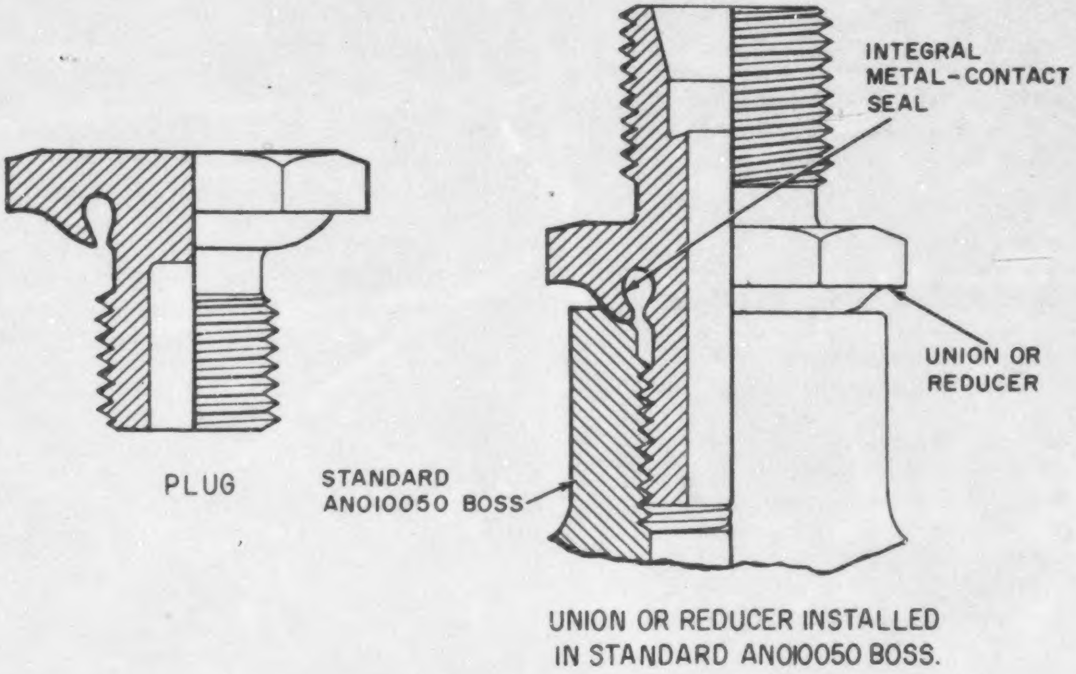
metal lip-seal plug and union or reducer. These fittings are identical in application to the conventional fluid fitting common to most AM's.

The major difference between conventional type fluid fittings and the lip-seal type is the manner in which they form a fluid pressure seal when installed in the port of a hydraulic component. The conventional fitting requires the use of an O-ring seal. The metal lip-seal fittings utilize an integral metal contact seal (fig. 10-5).

When the lip-seal fittings are installed in the port of a component and properly tightened, the metal contact seal area provides pressure-assist type sealing without the use of O-rings. The two types of fittings are completely interchangeable; however, the lip-seal fittings provide better system integrity because of the absence of O-rings.

REMOVAL AND REPLACEMENT OF DAMAGED TUBING

All tubing is pressure tested prior to installation and is designed to withstand several times the operating pressure to which it will be subjected. If a tube bursts or cracks, it is generally the result of excessive vibration, improper installation, or from damage caused by


INTEGRAL METAL-CONTACT SEAL
UNION OR REDUCER
PLUG
STANDARD AN010050 BOSS
UNION OR REDUCER INSTALLED IN STANDARD AN010050 BOSS.

AM.933

Figure 10-5.—Metal lip-seal fittings.

collision with an object. All tubing failures should be carefully studied and the cause of the failure determined if possible. Replacements should be of the same size and material as the original or an acceptable substitute. The applicable Maintenance Instructions Manual usually lists acceptable substitutes for the original material.

LAYOUT OF LINES

A damaged line should be carefully removed so that it may be used as a template or pattern for the replacement item. If the old piece of tubing cannot be used as a pattern, an acceptable one can be made by placing one end of a piece of soft iron wire into one of the fittings where the tube is to be connected. Form the necessary bends in order to place the opposite end of the wire into the other connection. When the template satisfactorily spans the area between the fittings, it can be used as a pattern to bend the new tube.

Select a path with the least total degrees of bend, as this reduces flow loss and simplifies bending. Use a path with all bends in the same plane, if possible.

Never select a path that requires no bends. A tube cannot be cut or flared accurately enough so that it can be installed satisfactorily without bends. Bends are also necessary to permit the tubing to expand or contract under temperature changes and to absorb vibration. If the tube is small (under 1/4 inch) and can be hand formed, casual bends may be made to allow for this. If the tube must be machine formed, definite bends must be made to avoid a straight assembly.

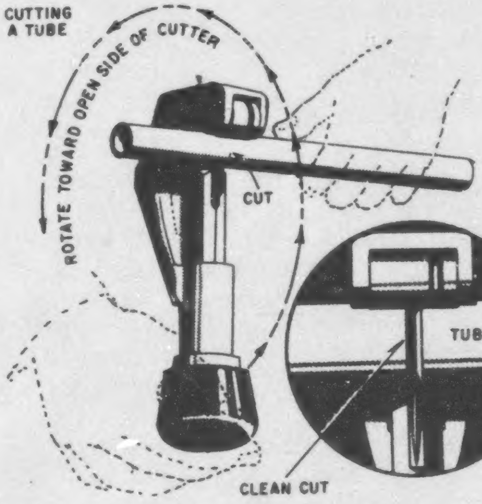
Care must be taken to start all bends a reasonable distance from the end fittings, as the sleeves and nuts must be slipped back along the tube during the fabrication of flares and during inspections. In all cases, the new tube assembly should be so formed prior to installing that it is not necessary to PULL or DEFLECT the assembly into alignment by means of the coupling nuts.

TUBE CUTTING

The ideal objective, when cutting tubing, is to produce a square end, free from burrs. Tubing may be cut with a tube cutter or a fine-tooth hacksaw.

Correct use of the tube cutter is shown in figure 10-6. The procedure is as follows: Place the tube in the cutter with the cutting wheel at the point where the cut is to be made. Tighten the adjusting knob so as to apply light cutter pressure on the tube, then rotate the cutter toward its open side, as shown in the illustration. As the cutter is rotated about the tube, continue to apply light pressure to the cutting wheel by intermittently tightening the knob. Too much pressure applied to the cutting wheel at one time may deform the tubing or cause excessive burrs. After the cut is completed, remove all burrs inside and outside, then clean the tube to make sure no foreign particles remain.

If a tube cutter is not available, a fine-tooth (32 teeth per inch) hacksaw may be used in cutting tubing. A convenient method of holding tubing when cutting it with a hacksaw is to place the tube in a flaring block and clamp the block in a vise. After cutting tubing with a hacksaw all saw marks must be removed by filing. After



AM.70

Figure 10-6.—Tube cutting.

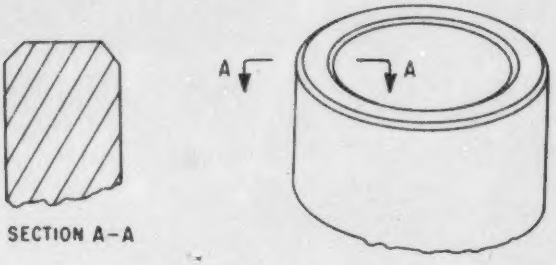


Figure 10-7.—Properly burred tubing.

filing, remove all burrs and sharp edges from the inside and outside of the tube as shown in figure 10-7. Clean out the tube and make sure no foreign particles remain.

TUBE BENDING

The objective in tube bending is to obtain a smooth bend without flattening the tube. Tube bending is usually accomplished with one of the tube benders discussed in this section; however, in case of an emergency, aluminum tubing under 1/4 inch in diameter may be bent by hand.

Hand Tube Bender

The hand tube bender (fig. 10-8) consists of four parts—handle, radius block, clip, and slide bar handle. The radius block is marked in degrees of bend ranging from 0 to 180. The slide bar handle has a mark which is lined up with the zero mark on the radius block. The tube is inserted in the tool; and after lining up the marks, the slide bar handle is moved around until the mark on the slide bar handle reaches the desired degrees of bend on the radius block.

Mechanical Tube Bender

The tube bender shown in figure 10-9 is issued as a kit. The kit contains the equipment necessary for bending tubing from 1/4 inch to 3/4 inch in diameter.

This tube bender is designed for use with aircraft grade, high-strength, stainless-steel tubing, as well as all other metal tubing. It is designed to be fastened to a bench or tripod, and the base is formed so as to provide a secure grip in a vise.

The simple hand bender shown in figure 10-8 uses two handles as levers to provide the mechanical advantage necessary to bend the tubing, while this type tube bender employs a handcrank and gears. The forming die is keyed to the drive gear and secured by a screw (fig. 10-9).

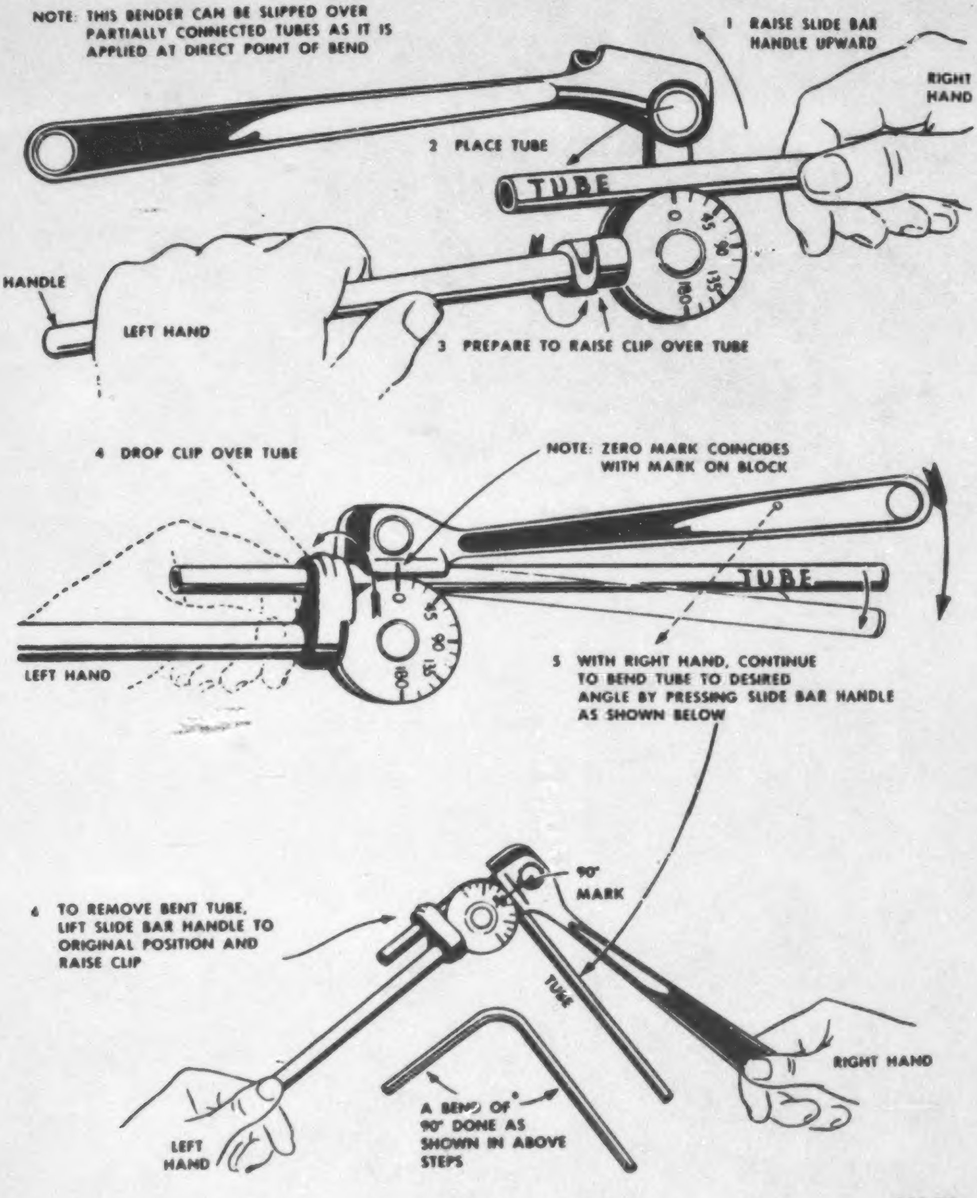
The forming die on the mechanical tube bender is calibrated in degrees similar to the radius block of the hand type bender. A length of replacement tubing may be bent to a specified number of degrees or it may be bent to duplicate the bend in the damaged tube or pattern. Duplicating the bend of a damaged tube or pattern is accomplished by laying the pattern on top of the tube being bent and slowly bending the new tube to the required bend. NOTE: Certain types of tubing are more elastic than others; therefore, it may be necessary to bend the tube past the required bend to allow for springback.

TUBE FLARING

A hand flaring tool similar to that shown in figure 10-10 is usually used for single flaring tubing. This tool consists of a flaring block or grip die, a yoke, and a plunger or flaring pin. The grip die consists of two steel blocks hinged at one end and held in alignment by a pilot pin. A number of countersunk holes, varying in size to conform with tube diameters and with countersinks matching standard flare angles and radii, are provided with half of the hole in each block.

The yoke fits over the two halves of the grip die and has a setscrew which is used to lock the yoke at the desired position. The yoke also serves as a centering guide for the plunger. The plunger is tapered to the same angle as the countersunk holes in the grip die.

To flare the end of a tube with this tool, slip the fitting nut and sleeve onto the tube and place the tube in the proper size hole in the grip die. (The end of the tube should extend 1/64


NOTE: THIS BENDER CAN BE SLIPPED OVER PARTIALLY CONNECTED TUBES AS IT IS APPLIED AT DIRECT POINT OF BEND

1 RAISE SLIDE BAR HANDLE UPWARD

2 PLACE TUBE

3 PREPARE TO RAISE CLIP OVER TUBE

4 DROP CLIP OVER TUBE

NOTE: ZERO MARK COINCIDES WITH MARK ON BLOCK

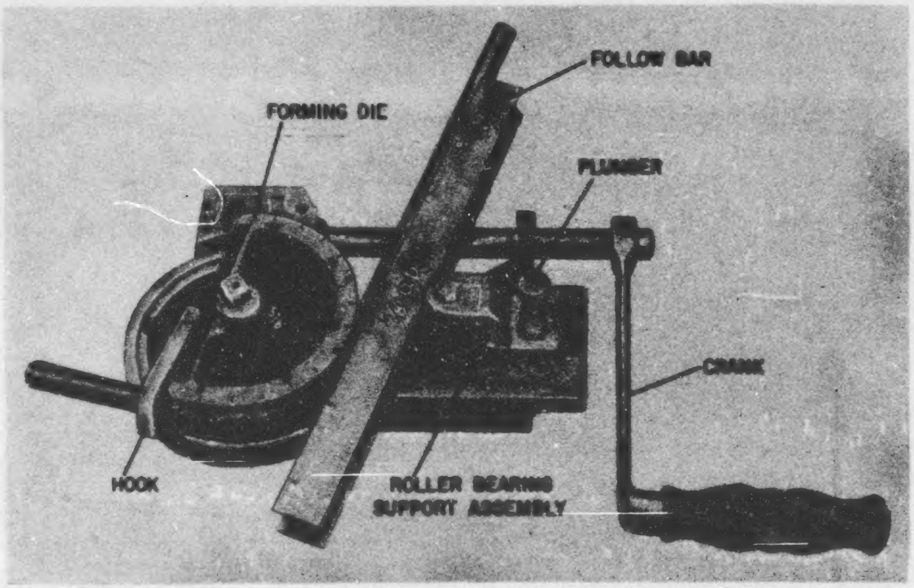
5 WITH RIGHT HAND, CONTINUE TO BEND TUBE TO DESIRED ANGLE BY PRESSING SLIDE BAR HANDLE AS SHOWN BELOW

6 TO REMOVE BENT TUBE, LIFT SLIDE BAR HANDLE TO ORIGINAL POSITION AND RAISE CLIP

A BEND OF 90° DONE AS SHOWN IN ABOVE STEPS

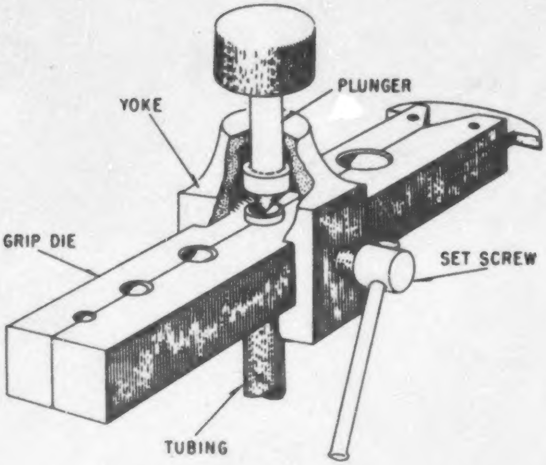
Figure 10-8.–Tube bending.

inch above the surface of the grip die.) Center the plunger over the end of the tube and tighten the yoke setscrew to secure the tubing in the grip die and hold the yoke in place. The flare is made by striking the plunger several light blows with a hammer or mallet. Turn the plunger a half turn after each blow and make sure it seats properly before removing the tube from the grip die. After completing the flare, inspect to insure that no cracks are evident.



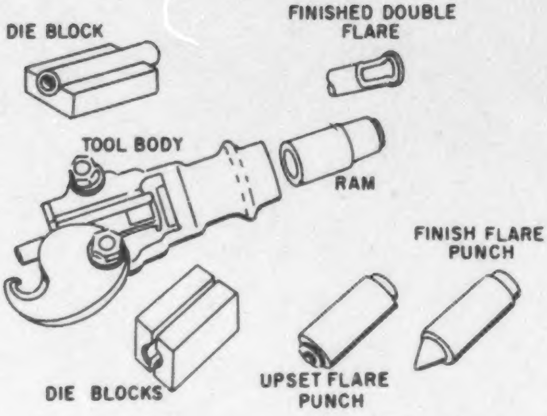
AM.73

Figure 10-9.—Mechanical tube bending tool.



AM.74

Figure 10-10.—Tube flaring tool (single flare).



AM.75

Figure 10-11.—Tube flaring tool (double flare).

NOTE: The flared end of the tube should not be any larger than the largest diameter on the sleeve being used.

Double flares should be used on all 5052 aluminum alloy tubing up to 3/8-inch diameter. Steel tubing need not be double flared. The double flare reduces cutting of the flare by overtightening and the consequent failure of the tubing assembly under operating pressure. Aluminum alloy tubing used in low-pressure oxygen systems should always be double flared. Figure 10-11 shows one of the tools used in the manufacture of double flared tube assemblies.

This flaring tool is issued as a kit. The kit contains a tool body, a ram, and a finish flare punch. Also included are a set of die blocks and an upset flare punch for each size of tubing which may be flared with this kit.

To double flare a tube assembly, prepare the end of the tube as shown in figure 10-7. Select the proper size die blocks and proceed as follows:

1. Place one-half of the die block in the flaring tool body with the countersunk end towards the ram guide.
2. Install the nut and sleeve and lay the tubing in the die block with approximately 1/2 inch protruding beyond the countersunk end.
3. Place the other half of the die block into the tool. Close the latch plate and tighten the clamp nuts finger tight.
4. Insert the upset flare punch in the tool body with the gage end toward the die blocks.

   NOTE: One end of the upset flare punch is counter-bored or recessed to gage the amount of tubing needed to form a double lap flare. Insert the ram and tap lightly with a hammer or mallet until the upset flare punch meets the die blocks and the die blocks are firmly set against the stop plate on the bottom of the tool.
5. Tighten the latch plate nuts with a wrench. Tighten the nuts alternately, beginning with the closed side to prevent distortion of the tool.
6. Reverse the upset flare punch and insert it in the tool body. Insert the ram into the tool body and tap lightly with a hammer or mallet until the upset flare punch contracts the die blocks.
7. Remove the upset flare punch and ram. Insert the finishing flare punch and ram. Tap the ram lightly until a good seat is formed. Always check the seat at intervals during the finishing operation to avoid overseating.

A finished double flare is shown in figure 10-11.

CAUTION: When fabricating oxygen lines, insure that all tools are kept free of oil and grease.

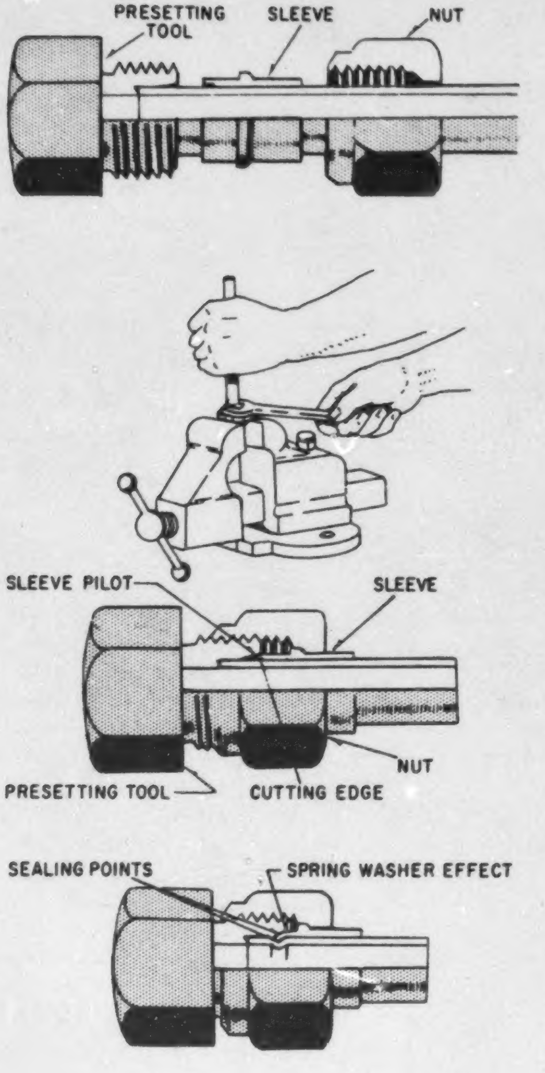
PRESETTING FLARELESS TUBE FITTINGS

Although the use of flareless-tube fittings eliminates all tube flaring, another operation, referred to as PRESETTING, is necessary prior to installation of a new flareless-tube assembly. Presetting is necessary to form the seal between the sleeve and the tube without damaging the connector.

Presetting should always be accomplished with a presetting tool as shown in figure 10-12. These tools are machined from tool steel and hardened so that they may be used with a minimum of distortion and wear. It is recommended that a mandrel be used during the sleeve presetting operation. A mandrel consists of a short piece of solid bar of any hard material such as steel. It should have an outside diameter of 0.002 to 0.005 inch less than the inside diameter of the tube. Using a mandrel assists in attaining an improved sleeve cut during the presetting operation. For field use, a short piece of drill rod of the proper diameter may be used as a mandrel. The mandrel should be long enough to support the tube inside diameter at the sleeve cut and also at the point where the sleeve shoulder grips the tube.

NOTE: A connector may be used as a presetting tool in an emergency. However, when connectors are used as presetting tools, aluminum connectors should be used only once and steel connectors should not be used more than five times. The presetting operation is described in the following paragraphs.

NOTE: There are two types of flareless-tube fittings in current use. The older type consists of a short sleeve (MS21918) and a long nut (MS21917). The newer type consists of a long sleeve (MS21922) and a short nut (MS 21921). The presetting operation for the two types



AM.76

Figure 10-12.—Presetting flareless-tube assembly.

differs to some extent. These differences are pointed out as applicable in the following discussion.

1. Cut the tubing to the correct length, with the ends perfectly square. Burr the inside and outside of the tube. Slip the nut and then the sleeve over the tube, making certain that the pilot and the cutting edge of the sleeve point toward the end of the tube. (See fig. 10-12.) If a mandrel is used, it should be inserted in the tube at this time.

2. Lubricate the threads of the presetting tool and the nut with the approved lubricant. Hydraulic fluid, Specification MIL-H-5606, is the approved lubricant for hydraulic lines; and pneumatic grease, Specification MIL-G-4343, is the approved lubricant for pneumatic lines. Refer to NA 01-1A-20, Aviation Hose Assembly and Tube Repair, for the approved lubricants for other systems.

CAUTION: Hydraulic fluid or any other petroleum base lubricants must not be used as a thread lubricant for oxygen lines.

3. Place the tool in a vise and hold the tubing firm and square on the seat in the tool. (The end of the tube must bottom firmly in the tool.) The tube should be rotated slowly between the thumb and fingers while the nut is turned down until the sleeve seizes on the tube. When the tube no longer turns, the nut is ready for final tightening.

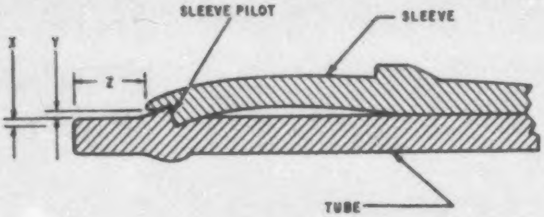
4. The final tightening force necessary to set the sleeve on the tube depends on the type of fitting. When presetting the older type fittings, tighten the nut (MS21917) 1 1/6 more turns for all sizes of tubing and all types of tubing material. This force sets the sleeve (MS21918) on the tube.

When presetting the newer type fitting–the long sleeve (MS21922) and the short nut (MS21921)–the required tightening force varies. If a mandrel is used, the final tightening force varies with the size of the tubing. If a mandrel is not used, the tightening force varies with the size, wall thickness, and material of the tubing. Tables of these tightening forces (turn values) are presented in NA 01-1A-20. These tables should be consulted when presetting this type fitting.

The final tightening force permanently assembles the sleeve to the tube. Sleeves should not be removed from the tube and reused under any conditions.

After presetting (fig. 10-13), the nut should be uncoupled from the presetting tool, and the sleeve and tube inspected for the following:

1. The sleeve cutting lip should be embedded



AM.703
Figure 10-13.–Preset sleeve–flareless-tube fitting.

into the tube outside diameter approximately 0.003 to 0.008 inch (distance (X) in figure 10-13), depending on the size and material of the tubing. As shown, a lip of material will be raised under the pilot. The pilot of the sleeve should contact or be quite close to the outside diameter of the tube. (See distance (Y).) The tube projection from the pilot of the sleeve to the end of the tube (distance (Z)) should be approximately as listed in table 10-2. These figures will vary with wall thickness for a given size.

2. A slight collapse of the inner diameter of the tube at the sleeve cut and at the shoulder is permissable.

3. The sealing surface of the sleeve must be smooth and free from nicks and scratches.

Table 10-2.–Distance from sleeve to tube end.

Tube size	Approximate tube projection (inches)
3/16	7/64
1/4	7/64
5/16	5/32
3/8	11/64
1/2	3/16
5/8	13/64
3/4	7/32
1	15/64

4. The sleeve should be slightly bowed and rotation of the sleeve is permitted. A 1/64-inch lengthwise movement of the sleeve is also permitted.

5. As a final check to determine that the fitting is properly preset, it should be proof tested at a pressure equal to twice the intended working pressure.

INSTALLATION OF TUBE ASSEMBLIES

Before a tubing assembly is installed in an aircraft, it should be carefully inspected. Dents and scratches should be removed (if possible without weakening the tube) prior to installation. The proper nuts and sleeves should be installed and a proper fit obtained where the tubing is flared. Flareless assemblies should be checked for proper presetting. Each tube assembly should be proof pressure tested to twice its operating pressure prior to installation. The tubing assembly should be clean and free from all foreign matter.

The nuts should be hand screwed to the mating connector, then tightened with the proper wrench. The tubing assembly should not have to be pulled into place with the nut, but should be properly aligned prior to tightening.

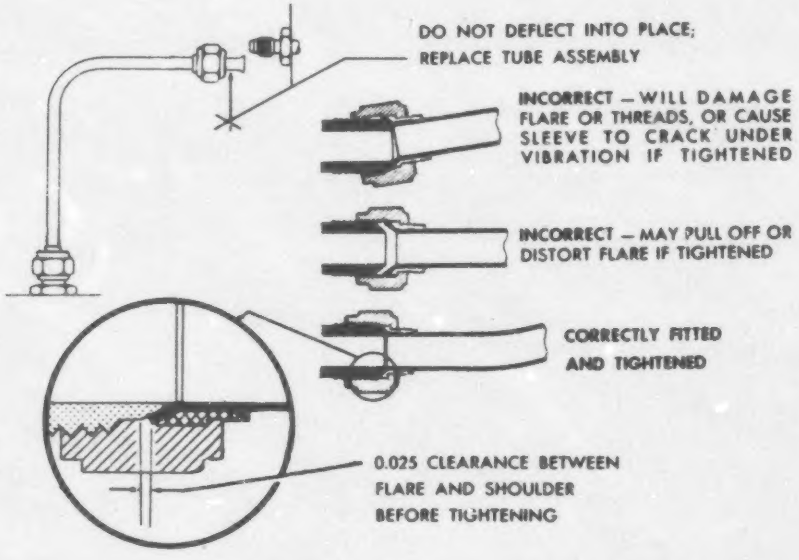
Tubing which runs through cutouts should be installed with care so that it will not be scarred when worked through the hole. If the tubing assembly is long, the edges of any cutouts should be taped before the tubing is installed.

It is important to tighten tube fitting nuts properly. A fitting wrench or open end wrench should be used when tightening tube connections. NOTE: Pliers should never be used to tighten tube connections.

Flared-Tube Assemblies

Correct and incorrect methods of installing flared-tube assemblies are illustrated in figure 10-14. Proper torque values are given in tables 10-3 and 10-4. It must be remembered that these torque values are for flared-tube fittings only.

If an aluminum alloy tube assembly leaks after tightening to the required torque, it must not be tightened further. Overtightening may severely damage or completely cut off the


DO NOT DEFLECT INTO PLACE;
REPLACE TUBE ASSEMBLY
INCORRECT – WILL DAMAGE FLARE OR THREADS, OR CAUSE SLEEVE TO CRACK UNDER VIBRATION IF TIGHTENED
INCORRECT – MAY PULL OFF OR DISTORT FLARE IF TIGHTENED
CORRECTLY FITTED AND TIGHTENED
0.025 CLEARANCE BETWEEN FLARE AND SHOULDER BEFORE TIGHTENING

AM.77

Figure 10-14.—Correct and incorrect method of installing flared fittings.

tubing flare or may result in damage to the sleeve or nut. The leaking connection should be disassembled and the fault corrected. Common faults are as follows:

1. Flare distorted into the nut threads.
2. Sleeve cracked.
3. Flare out of round.
4. Flare cracked or split.
5. Inside of flare rough or scratched.
6. Connector mating surface rough or scratched.
7. Threads of connector or nut dirty, damaged, or broken.

If a steel tube assembly leaks, it may be tightened 1/6 turn beyond the noted torque in an attempt to stop the leakage; then if unsuccessful, it must be disassembled and repaired.

Undertightening of connections may be serious, as this can allow the tubing to leak at the connector because of insufficient grip on the flare by the sleeve. The use of a torque wrench will prevent undertightening.

CAUTION: A nut should never be tightened when there is pressure in the line, as this will tend to damage the connection without adding any appreciable torque to the connection.

Flareless-Tube Assemblies

When installing flareless-tube assemblies, inspect to insure that no scratches or nicks are evident and that the sleeve is properly preset.

Lubricate the threads of the nuts and connectors with hydraulic fluid. Place the assembly in the proper position in the aircraft and finger tighten clamps, brackets, supports, and nuts. The tubing ends should fit snugly in the connectors and require little pressure to hold them in place.

CAUTION: Hydraulic fluid must not be used to lubricate fluid line connections in oxygen systems.

Use the torque values listed in table 10-5 whenever possible while tightening flareless nuts.

Table 10-3.–Torque limits for flared tube fittings.

Tubing outside Diameter (inches)	Torque For AN818 Nut (inch-pounds)			
	Aluminium Alloy Tubing Flare AND10061 or AND 10078 With Aluminium Nuts		Steel Tubing Flare AND10061 With Steel Nuts	
	Min	Max	Min	Max
1/8	20	30	75	85
3/16	25	35	90	100
1/4	40	65	135	150
5/16	60	80	180	200
3/8	75	125	270	300
1/2	150	250	450	500
5/8	200	350	650	700
3/4	300	500	900	1000
1	500	700	1200	1400
1-1/4	600	900	1500	1800
1-1/2	600	900	2000	2300
1-3/4	750	1050	2600	2900
2	800	1100	3200	3600

Table 10-4.–Torque values for double flared type coupling nuts (oxygen system fittings).

Tube OD (inch)	Torque (inch-pounds)	
	Working torque	Maximum torque
5/16	100	125
3/8	200	250
1/2	300	400

If it is not possible to use a torque wrench, use the following procedure for tightening nuts.

Tighten the nut be hand until an increase in resistance to turning is encountered. Should it be impossible to run the nut down with the fingers, use a wrench, but be alert for the first signs of bottoming. It is important that the final tightening commence at the point where the nut just begins to bottom.

With a wrench, turn the nut 1/6 turn (one flat on a hex nut). Use a wrench on the connector to prevent it from turning while tightening the nut. After the tube assembly is installed, the system should be pressure tested. Should a connection leak, it is permissible to tighten the nut an additional 1/6 turn (making a total of 1/3 turn). If, after tightening the nut a total of 1/3 turn, leakage still exists, the assembly should be removed and the components of the assembly inspected for scores, cracks, presence of foreign material, or damage from overtightening.

NOTE: Overtightening a flareless-tube nut drives the cutting edge of the sleeve deeply into the tube, causing the tube to be weakened to the point where normal in-flight vibration could cause the tube to shear. After inspection (if no

Table 10-5.--Torque values for flareless fittings.

WRENCH TORQUE FOR 304 1/8 H STEEL TUBES

Tube outside diameter	Wall thickness	Wrench torque inch-pounds
3/16	0.016	90-110
3/16	0.020	90-110
1/4	0.016	110-140
1/4	0.020	110-140
5/16	0.020	100-120
3/8	0.020	170-230
3/8	0.028	200-250
1/2	0.020	300-400
1/2	0.028	400-500
1/2	0.035	500-600
5/8	0.020	300-400
5/8	0.035	600-700
5/8	0.042	700-850
3/4	0.028	650-800
3/4	0.049	800-960
1	0.020	800-950
1	0.065	1600-1750
WRENCH TORQUE FOR 304-1A or 3471A STEEL TUBES		
3/8	0.042	145-175
1/2	0.028	300-400
1/2	0.049	500-600
1	0.035	750-900
WRENCH TORQUE FOR 6061-T6 or T4 TUBES		
1/4	0.035	110-140
3/8	0.035	145-175
1/2	0.035	270-330
1/2	0.049	320-380
5/8	0.035	360-440
5/8	0.049	425-525
3/4	0.035	380-470
1	0.035	750-900
1 1/4	0.035	900-1100

discrepancies are found), reassemble the connections and repeat the pressure test procedures.

CAUTION: Do not in any case tighten the nut beyond 1/3 turn (two flats on the hex nut); this is the maximum the fitting may be tightened without the possibility of permanently damaging the sleeve and tube.

Brazed Hydraulic Tube Assemblies

Brazed hydraulic tubing systems are appearing in many of the later model aircraft within the Navy. The brazed hydraulic tubing system includes a multi-branch feature which results in

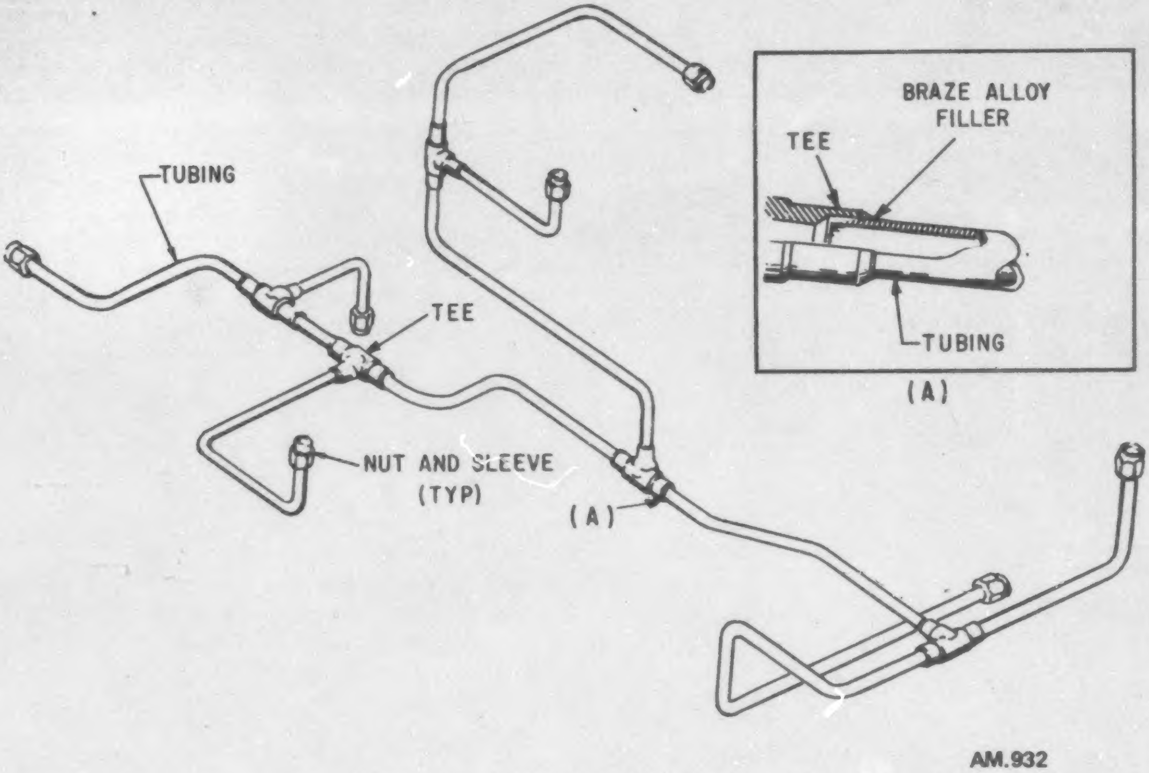


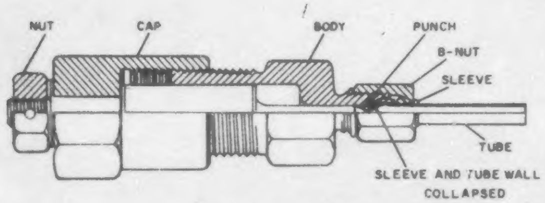
Figure 10-15.–Brazed hydraulic tubing assembly.

fewer threaded connections and the near elimination of 0-ring seals. A typical example of a brazed hydraulic assembly is provided in figure 10-15. Brazed tubing assemblies are made of rigid corrosion-resistant steel and assembled with sleeves and coupling nuts. Individual segments of the assembly are generally identified by separate part number and dash number and are brazed together into an assembly. On some aircraft such as the A-4F, a direction-of-flow arrow is electroetched on each individual segment of each tube assembly.

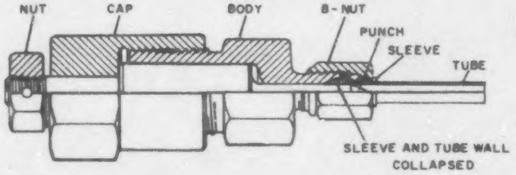
Maintenance of brazed tubing is limited to identification marking maintenance, sleeve sizing, segment repair, or complete assembly replacement. Tubing identification maintenance consists of installing color band tape on new tubing assemblies and on existing assemblies where the color bands have become lost, worn, or illegible. The requirements, location, and precautions for installing color band identification are covered in Structural Hardware, NavAir 01-1A-8.

Overtightening of the B-nut on the flareless type fitting used to connect most brazed tubing assemblies usually results in damage to the sleeve and consists of a necking down or swagging of the tip. This necking down can usually be corrected by the use of a sleeve sizing punch assembly as illustrated in figure 10-16. Because of the malleability of the sleeve material, sizing can be accomplished several times before the prospect of material failure would require replacement of that segment.

SLEEVE SIZING.–The sleeve sizing procedure can be accomplished without removing the line assembly from the aircraft, space permitting. The tube assembly is disconnected and drained, then the end of the tubing assembly to be sized and the threaded body on the punch assembly are lubricated with hydraulic fluid. Connect the B-nut on the end of the tube



PUNCH RETRACTED



PUNCH EXTENDED

AM.934

Figure 10-16.—Sleeve sizing—flareless fitting.

assembly to the threaded part of the body on the punch assembly fingertight. Using a wrench to hold the body, tighten the B-nut 1/6 turn (one hex side) beyond fingertight. Next, still holding the body of the punch assembly, slowly turn the cap on the punch assembly until the punch is bottomed in the extended position. Reverse the wrench action to withdraw the punch. Disconnect the punch assembly from the tube assembly and inspect the sleeve. Slight collapse of the tube assembly is permissible. No nicks or scoring marks are allowed on the sleeve, and no movement of the sleeve except rotation is permissible. Pressure test the repaired assembly for leakage as specified in the applicable MIM. If the pressure test is positive, reconnect the tube assembly to the aircraft system, air-bleed the lines, and service the hydraulic system.

SEGMENT REPAIR.—Whenever a segment or a fitting of a brazed tubing assembly has been damaged, it can generally be repaired. Figure 10-17 provides an example of typical segment repairs to a damaged assembly. With all pressure relieved in the system to be repaired, disconnect all couplings. Cap or plug all openings on adjacent lines and components to prevent loss of fluid and contamination. Cap or plug all openings on the tube assembly except two, one at the highest and one at the lowest openings. Pour solvent (P-D-680) into the highest opening to remove all hydraulic residue. Connect 20 to 40 psi of air pressure upstream of any cutting, burring, and sleeve presetting operations and insure that the coupling downstream is open for purge air exit. This will prevent entry of metal particles in the hydraulic system. The procedures for repair of such tubing assemblies may vary slightly in the various MIM's. Following repair, the assembly must be tested.

Oxygen System Tube Assemblies

Care must be taken at all times to keep the tubing clean and free of foreign matter during installation. Thread antiseize compounds and tapes should not be used on flared tubing fitting threads. Antiseize tape (MIL-T-27730A) may be used on tapered pipe fitting threads.

Pipe threaded fittings should be started by hand. A torque wrench should be used to tighten all pipe threaded fittings. The torque values for pipe threaded fittings are listed in table 10-6.

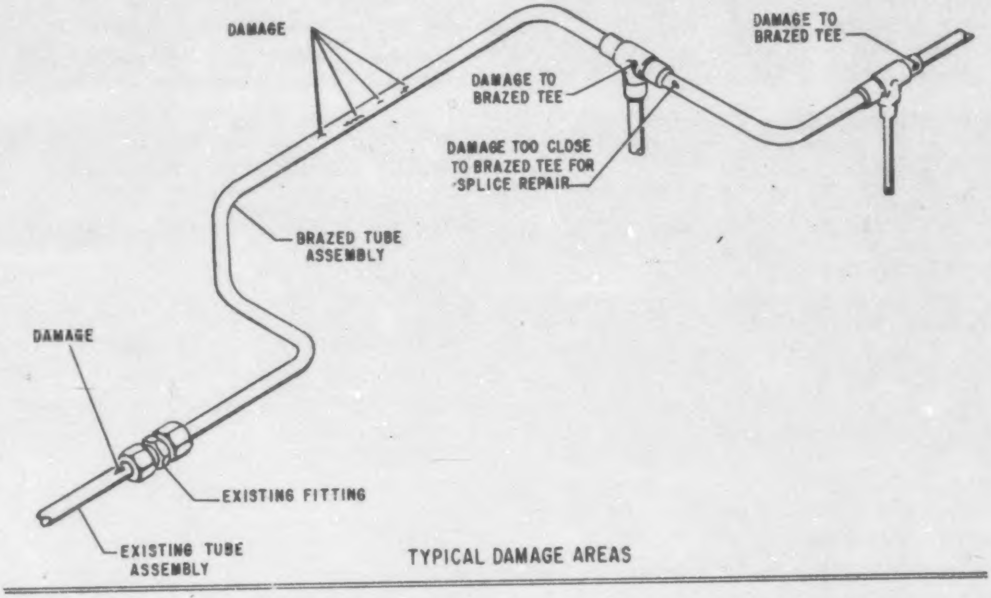
CAUTION: The importance of the following cannot be overemphasized: It is imperative that all oxygen equipment, lines, and fittings be kept free from GREASE, DIRT, OIL, HYDRAULIC FLUID, AND LEAKS. Leakage in oxygen system connections should be eliminated since the leakage rate may increase with time and vibration.

FLEXIBLE HOSE

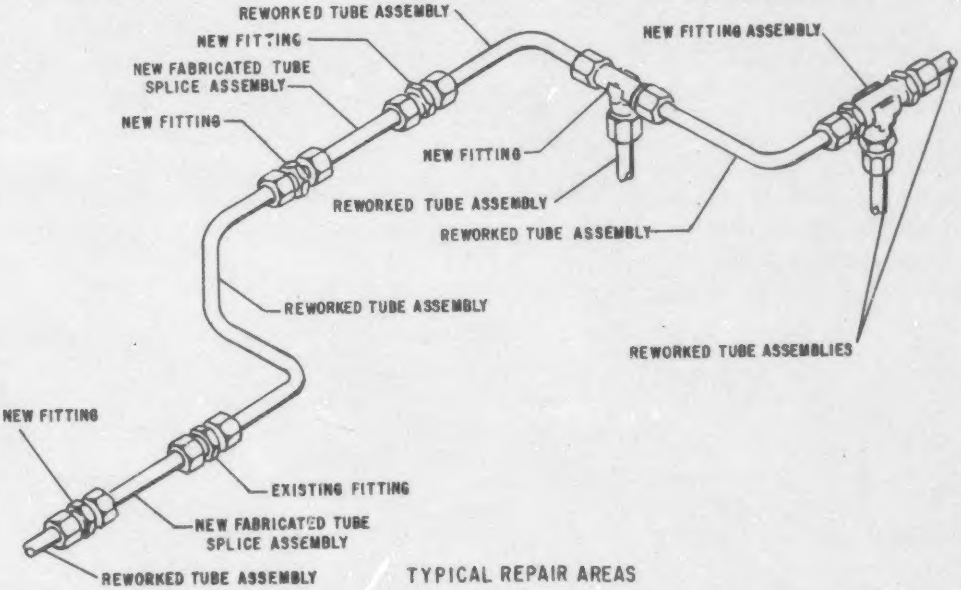
Flexible hose is used in connecting moving parts with stationary parts and in locations subject to severe vibration. It is heavier than aluminum alloy tubing and deteriorates rapidly; therefore, it is used only where absolutely necessary. The two types, rubber and Teflon flexible hose, are discussed in the following paragraphs.

RUBBER

Flexible rubber hose consists of a seamless synthetic rubber inner tube covered with layers



TYPICAL DAMAGE AREAS



TYPICAL REPAIR AREAS

AM.935

Figure 10-17.—Brazed tubing segment repair.

of cotton braid and wire braid, and an outer layer of rubber impregnated cotton braid. It is provided in low-pressure, medium-pressure, and high-pressure types. Figure 10-18 illustrates the hose which is commonly used in medium-pressure applications. This hose is identified by a Military Specification number, the hose size, the quarter year and year of manufacture, and the

Table 10-6.—Torque values for pipe threaded fittings (oxygen system).

Pipe thread (inch)	Torque (inch-pounds)	
	Minimum	Maximum
1/8	40	150
1/4	60	200
3/8	100	400

hose manufacturer's symbol. This information is stenciled on the hose at intervals of not more than 9 inches the entire length of the hose. The stenciled information indicates the natural lay of the hose.

The size of flexible hose is determined by the inside diameter (ID) and indicated by a numbering system identical to that used with rigid tubing. Therefore, the fittings used on No. 6 hose will be the same size and have the same threads as those used on No. 6 (3/8 inch) tubing.

High-pressure hose is available to the operating activity in complete assemblies only. These assemblies are equipped with swaged type fittings and are fabricated only by commercial activities and intermediate or depot maintenance level activities, because of the special tools required. Medium-and low-pressure hose assemblies are equipped with detachable type end fittings (described later) and may be fabricated at the intermediate maintenance level.

FABRICATION AND REPLACEMENT

Flexible hose must be replaced if peeling, flaking of the hose cover, or exposure of the fabric reinforcement to the elements occur.

When failure occurs in a flexible hose equipped with swaged end fittings, the unit is generally replaced without attempting a repair; that is, the correct length of hose, complete with factory-installed end fittings, is drawn from supply.

When failure occurs in low-pressure or medium-pressure hose equipped with detachable type end fittings, the replacement unit is usually fabricated by the AIMD. Undamaged end fittings on the old length of hose may be removed and reused; otherwise, new fittings must be drawn from supply along with a sufficient length of hose.

NOTE: Inspect bulk hose prior to use to insure that its shelf life has not expired.

Figure 10-19 illustrates one type of detachable end fitting. This fitting is intended for

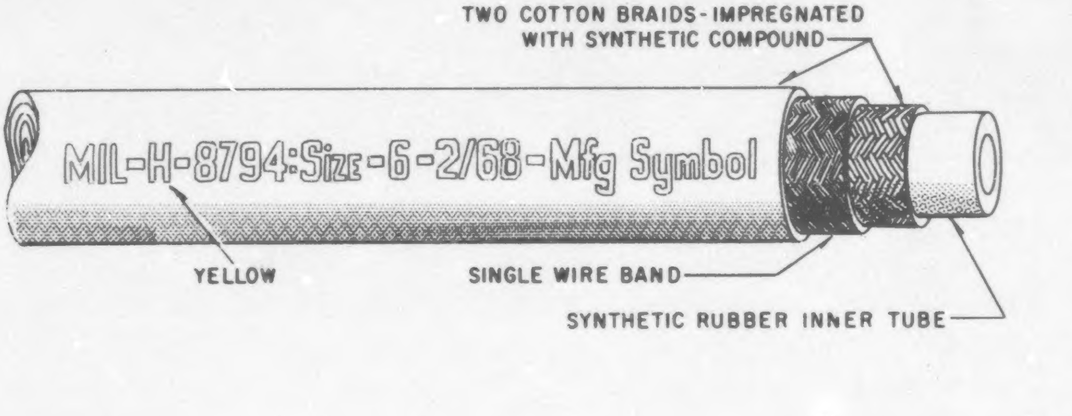
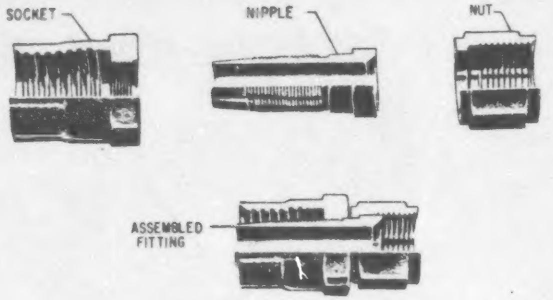
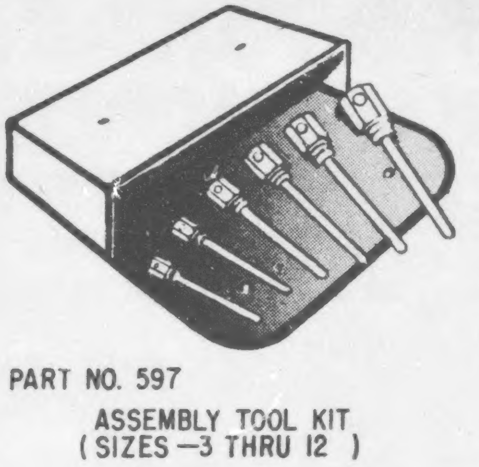

TWO COTTON BRAIDS-IMPREGNATED WITH SYNTHETIC COMPOUND
MIL-H-8794:Size-6-2/68-Mfg Symbol
YELLOW
SINGLE WIRE BAND
SYNTHETIC RUBBER INNER TUBE
AM.79

Figure 10-18.—Medium-pressure hose.



AM.80
Figure 10-19.–Sleeve type flexible hose fitting (MS-24587).



AM.81
Figure 10-20.–Medium-pressure hose assembly tool kit.

use with medium-pressure hose which conforms to Specification MIL-H-8794. This fitting is designed for use in flared-tube systems. Other hose fittings which are designed to be used with flareless-tube fittings are also available.

Assembly of Sleeve Type Fittings

A tool kit is available for assembling the MS-24587 fittings to MIL-H-8795 (medium-pressure) hose. Figure 10-20 illustrates the hose assembly tool kit, which contains the assembly tools for use on the smaller sizes (3/16 through 3/4 inch) of hose. If a tool kit is not available, the corresponding size AN-815 adapter may be used.

Figure 10-21 illustrates the steps in assembling the MS-24587 fitting, using the proper size assembly tool from the hose assembly tool kit.

After assembly, always make sure all foreign matter is removed from the inside of the hose by blowing out with compressed air.

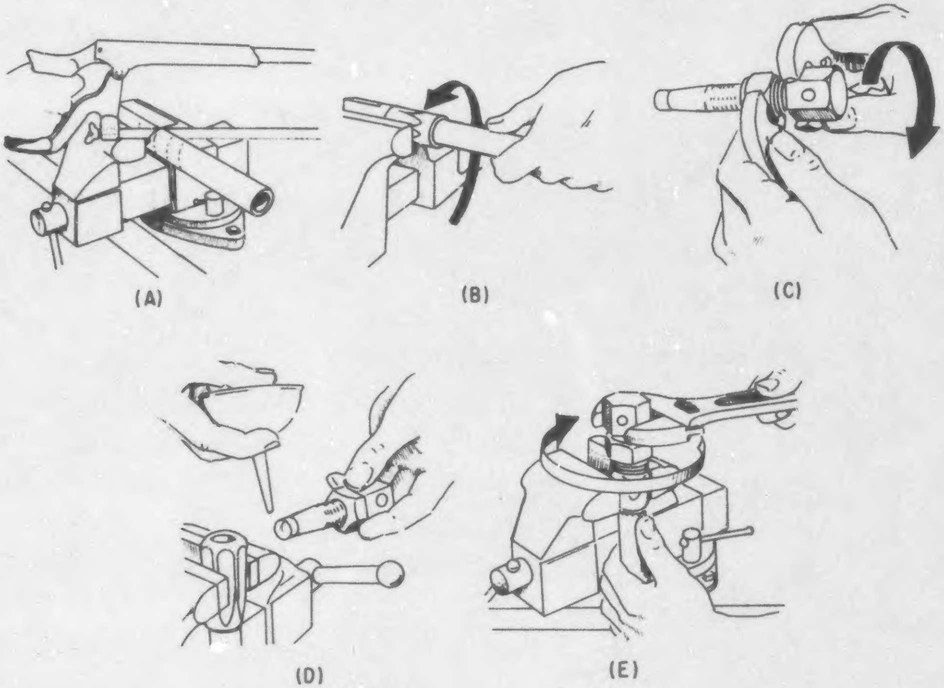
All shop-assembled flexible hose must be proof tested after assembly. Proof testing is accomplished by plugging or capping one end of the hose and applying pressure to the inside of the hose assembly.

Proof testing of shop fabricated hose assemblies should be accomplished in accordance with instructions contained in the applicable Maintenance Instructions Manual. In cases where proof test pressures are not included in the aircraft Maintenance Instructions Manual, refer to Aviation Hose Assembly and Tube Repair, NavAir 01-1A-20. Table 10-7 lists the prooftest pressures for a few sizes of medium-pressure (MIL-H-8795) hose when assembled with MS-24587 fittings for use in aircraft hydraulic systems.

Installation of Flexible Hose Assemblies

Flexible hose must not be twisted on installation, since this reduces the life of the hose considerably and may cause the fittings to loosen as well. Twisting of the hose can be determined from an identification stripe running along its length, or as in the case of medium-pressure hose (shown in figure 10-18) by the stenciled information that is used to identify the hose.

The minimum bend radius for flexible hose varies according to size and construction of the hose and the pressure under which the hose will operate. Tables and graphs showing minimum



AM.82

A. Clamp the hose in the vise and cut the required length with a fine tooth hacksaw.

B. Secure the socket in the vise. Turn the hose counterclockwise into the socket until it bottoms. Unscrew 1/4 turn.

C. Insert the nipple in the nut. Install the proper size assembly tool and tighten, using two wrenches.

D. Place the socket in the vise with the threaded end exposed. Lubricate the inside of the hose and the nipple threads with hydraulic fluid or light lubricating oil.

E. Using a wrench on the assembly tool, screw the nipple into the socket and hose. Exercise care to prevent the hose from turning. A clearance of 1/32 to 1/16 inch between the nut and socket is required so that the nut will swivel. Remove the assembly tool.

Figure 10-21.—Assembly of MS-24587 fitting to medium-pressure flexible hose.

Table 10-7.—Proof test pressures for medium-pressure hose assembled with MS-24587 fittings.

Hose size number	Operating pressure (psi)	Proof pressure (psi)	Burst pressure (psi)
4	3,000	6,000	12,000
5	3,000	5,000	10,000
6	2,000	4,500	9,000
8	2,000	4,000	8,000
10	1,750	3,500	7,000
12	1,500	3,000	6,000

bend radii for all types of installations are provided in Aviation Hose Assembly and Tube Repair, NA-01-1A-20. Bends which are too sharp will reduce the bursting pressure of flexible hose considerably below its rated value.

Flexible hose should be installed so that it will be subject to a minimum of flexing during operation. Hose must be supported at least every 24 inches. Closer supports are desired.

A flexible hose must never be stretched tight between two fittings. About 5 to 8 percent of its total length must be allowed as slack to provide freedom of movement under pressure. When under pressure, flexible hose contracts in length and expands in diameter.

TEFLON

Teflon hose is a flexible hose designed to meet the requirements of higher operating temperatures and pressures in present-day weapon systems. Teflon hose can generally be used in the same manner as rubber hose.

Teflon hose consists of a tetrafluorethylene resin which is precessed and extruded into tube shape to a desired size. It is covered with stainless steel wire which is braided over the tube for strength and protection. The advantages of this hose are its operating temperature range (-67°F to +450°F), its chemical inertness to all fluids normally used in hydraulic and engine lubrication systems, and its long life. At this time, only medium-pressure and high-pressure types are available and are complete assemblies with factory-installed end fittings. These fittings may be either the detachable type or the swaged type. When failures occur, replacement must be made on a complete assembly basis.

The size of Teflon hose is determined in the same way the size of rubber hose is determined.

Teflon hose, like rubber hose, has definite limits and particular characteristics that demand understanding and attention in the general handling during installation and removal. To insure its satisfactory function and reduce the likelihood of failure, the following rules should be observed when working with Teflon hose:

1. Do not exceed recommended bend limits.
2. Do not exceed twisting limits.
3. Clamp the hose assemblies at least every 24 inches (more closely if possible) to lend support enough to prevent bending and kinking.
4. Do not permit flexible hose to impinge on, and thus possibly deflect, rigid supporting lines.
5. Allow a slight slack in the hose line to accommodate changes in length that will occur when pressure is applied.
6. Do not straighten a bent hose that has taken a permanent set.
7. Do not hang, lift, or support objects from Teflon hose.

Maintenance

Teflon hose, like all aircraft parts, has definite wearability limits. The chafing caused by hose rubbing against other surfaces, for instance, has undermined many parts and systems. Disaster consequent to such wear can be averted only through frequent inspection and maintenance by alert maintenance and quality assurance personnel.

INSPECTION.—Whereas all rubber aircraft hose must be inspected for aging and associated deterioration immediately prior to installation, Teflon hose, being comparatively inert, is exempt from shelf-life control. However, Teflon hose assemblies must be visually inspected for leakage, abrasion, and kinking according to the aircraft inspection requirements in the applicable Maintenance Instructions Manuals. The presence and extent of the following possible defects must be determined.

Kinking.—Kinking is an imperfection induced in Teflon when it is bent at a closer angle (or shorter radius) than its characteristics allow. This is a common cause of failure, because Teflon hose tends to assume the shape of the position in which it is installed and becomes semipermanently set or "preformed" in these configurations. These so-called preformed hoses kink easily and their walls are severely weakened if they are excessively bent or twisted or if they are permitted to follow their natural tendencies to revert to their orientations. They must be handled very carefully while being removed and should be tied with wire that will hold them in shape pending reinstallation.

Excessive Cold Flow.—Cold flow is the name given the deep permanent impressions and cracks in the hose cover caused by the pressure of the hose clamps. Replace hose when cold flow becomes too deep.

Weather-Checking.—Weather-checking, the occurrence of numerous fine cracks caused by exposure to various weather conditions over extended periods, causes no serious damage as long as it does not expose the fabric of the hose cover. However, weather-checking deepened to the point of exposing this fabric can contribute to the weakening and eventual failure of hose.

To examine the extent of weather-checking, flatten the walls of the hose together, with force if necessary. If the cord fabric can be seen at any point, replace the hose. Replace the hose also if radial cracks at the end of the hose are deeper than one-eighth inch or are halfway from the ends of the hose to the clamps.

Internal Cracking.—Fuel hoses, both Teflon and rubber, dry out and crack when they lose the placticizer that keeps them pliable. Hoses remain pliable while in active use with gasoline flowing through them but lose their plasticizers when the fuel is drawn off.

Therefore, fuel lines of previously used aircraft that are to be returned to service after extended storage must be inspected for internal cracking. Those showing internal cracks, which are best revealed by pressing the hose with the fingers to widen imperfections, should be replaced, while those showing no visible cracks at either end are considered satisfactory throughout.

Separation of Outer Cover.—When the cotton-braid or rubber coverings of metal-reinforced hose become loose, frayed, or chafed to the point that the metal reinforcement is exposed or damaged, replace the hose. If a hose shows some wear but the metal is not exposed or damaged, wrap the frayed or chafed areas in flexible, electrical-insulation sleeving and secure it over the hose with support clamps.

Wire-Braid Damage.—Wire-braid damage is considered excessive when two or more wires in a single plait or six or more in an assembly (or lineal foot when assemblies are longer than 12 inches) are broken. Broken wires, where kinking of Teflon hose is suspected, are felt as sharp dents or twists in the braid.

CAUTION: When performing wire-braid damage check, the Teflon hose must always be handled with great care so that the wire-braid damage does not injure the hands.

CLEANING.—Teflon hose is nonabsorbent and nonadhesive, and is usually unaffected by fuels, lubricating oils, coolants, and solvents used around aircraft. It is easily cleaned in oleum spirits, kerosene, trichlorethylene, or synthetic detergents. When dipped in or flushed with the cleaning solution, the hose merely needs a slight brushing to remove the surface debris.

WARNING: Because some solvents are highly flammable and some toxic, proper precautions

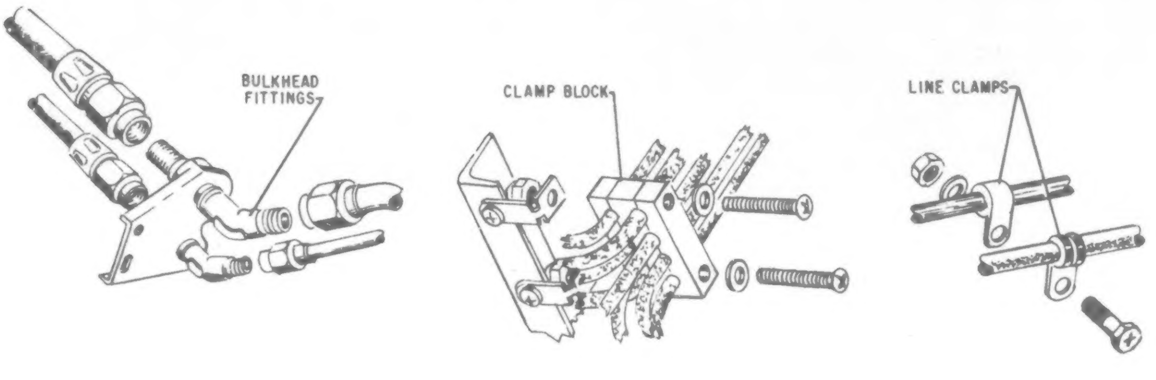


Figure 10-22.—Methods used to secure fluid lines.

must be taken when they are used. Prolonged inhalation of fumes must be avoided.

STORAGE.–When storing Teflon hose, be sure to:

1. Cap or plug the ends of all hose assemblies with metal or plastic plugs.
2. Tape hose ends to prevent wire flareout.
3. Store hose in straight position if possible. When it is necessary to coil hose, use the widest coil possible.

CLAMPS

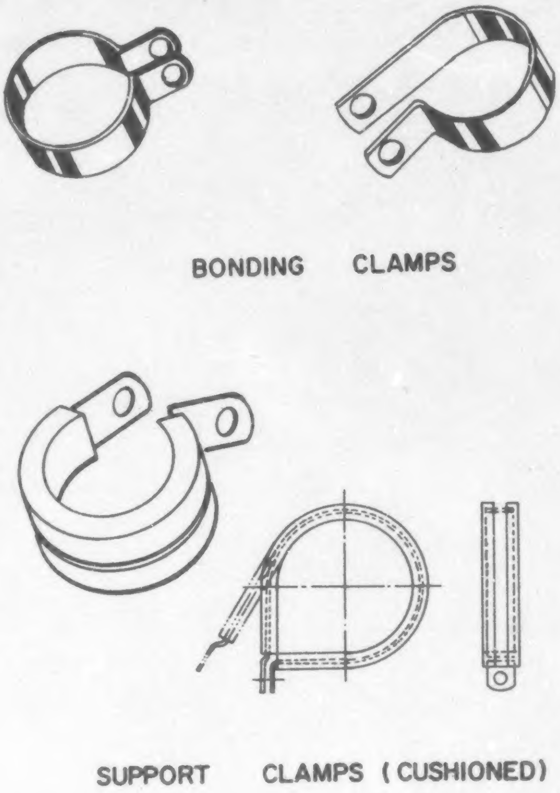
As stated earlier in this chapter there are hundreds of feet of tubing and flex hose running throughout the aircraft structure. These fluid lines are routed to follow the configuration of the aircraft structure to provide support for the lines. Clamps, bulkhead fittings, clips, brackets, and clamp blocks not only secure the lines to the adjacent structure, but also provide a dampening effect to prevent harmful vibration. Fluid lines must be kept separated from the aircraft structure and other lines to prevent chafing. Chafing (rubbing) of the lines can cause failure of the system. As the lines rub against each other or the aircraft structure, the wall thickness of the tubing is diminished until it can no longer withstand the fluid pressure, and the line ruptures. The three most common methods of securing fluid lines are shown in figure 10-22.

INSTALLATION OF CLAMPS

While performing maintenance actions the AMS may be required to remove clamps and/or clamp blocks. In all cases, unless directed by Aircraft Changes, Bulletins, etc., the clamp(s) and/or clamp block (x) with all of the necessary hardware (washers, spacers, nuts, screws and/or bolts) must be reinstalled.

CAUTION: Do not allow any dropped hardware to remain lying in the aircraft upon completion of maintenance actions.

The most abused and neglected are the line clamps which are used to properly bond (provide a path for static electricity) and support rigid tubing and flexible hose. Figure 10-23 shows both the plain bonding clamps and the cushioned steel clamp. The cushioning material may be either rubber or Teflon.



AM.78

Figure 10-23.–Bonding and support clamps.

Support clamps should be installed at 15-inch intervals and as close to tubing bends as possible. In no case should clamps be installed at intervals greater than 20 inches.

When tubing is supported to a structure or other rigid member, a minimum clearance of 1/16 inch must be maintained with the structure or member. A minimum clearance of 1/4 inch must be maintained between the tubing and adjacent rigid structure or moving components. Extra support clamps may be used in any installation to prevent vibration and chafing, or to provide line clearance.

Figure 10-24 illustrates six ways to secure fluid lines to each other using support clamps to maintain line clearance and prevent chafing due

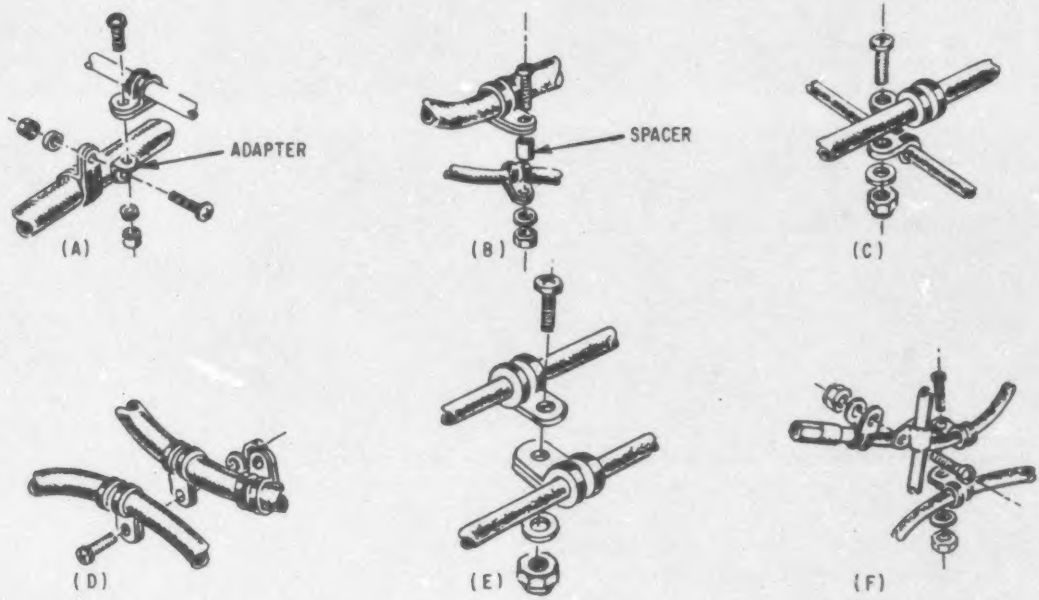
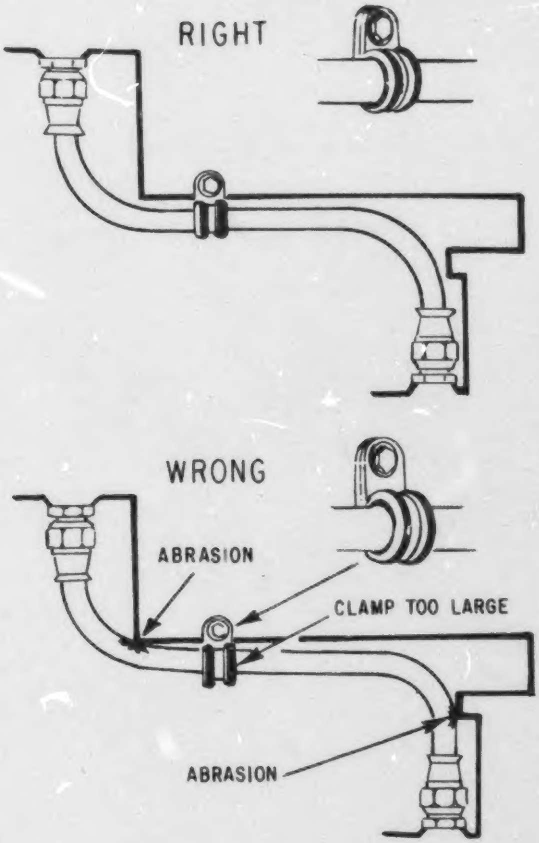


Figure 10-24.—Securing lines using support clamps.

to vibration. In view (A) an adapter is used to maintain the desired line clearance. View (B) illustrates the use of a spacer, and views (C), (D), (E), and (F) show the use of support clamps positioned in such a manner as to separate the fluid lines properly.

Figure 10-25 shows a flexible hose secured to the aircraft structure. The lower view shows what could happen if too large a clamp were used.



AM.417

Figure 10-25.—Installation procedures (right and wrong).

CHAPTER 11

CORROSION CONTROL

CORROSION

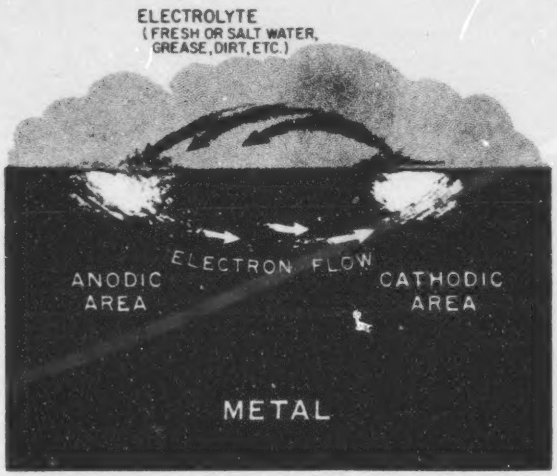
Modern high-speed aircraft are dependent upon the structural soundness of the metals which make up the largest percentage of their thousands of parts. The greatest threat to structural integrity of naval aircraft is metals corrosion. With higher strength demands being made of aircraft metals and the closer tolerances of flight safety demanded, these aircraft would rapidly become inoperative without regular anti-corrosion attention.

Corrosion endangers the aircraft by reducing the strength and changing the mechanical characteristics of the materials used in its construction. Materials are designed to carry certain loads and withstand given stresses as well as to provide an extra margin of strength for safety. Corrosion can weaken the structure thereby reducing or eliminating this safety factor. Replacement or reinforcement operations are costly, time-consuming, and reduce usage of the aircraft. Severe corrosion can cause failure of parts or systems which is an obvious danger. Corrosion in vital systems can cause malfunctions that endanger the safety of flight, and such dangers reemphasize the importance of corrosion control.

Metals corrosion is the deterioration of metals as they combine with oxygen to form metallic oxides. This combining is a chemical process which is essentially the reverse of the process of smelting the metals from their ores. Very few metals occur in nature in the pure state. For the most part they occur naturally as metallic oxides. These oxides may also be mixed with other undesirable impurities in the ores. The refining processes generally involve the extraction of relatively pure metal from its ore and the addition of other elements (either metallic or nonmetallic) to form alloys. Alloying constituents are added to base metals to develop a variety of useful properties. For example, in aircraft structural applications, high strength-to-weight ratios are the most desirable properties in all alloys.

After refining, regardless of whether or not alloyed, base metals possess a potential or tendency to return to their natural state. However, potential is not sufficient in itself to initiate and promote this reversion. There must also exist a corrosive environment, in which the significant element is oxygen. It is the process of oxidation—combining with oxygen—that causes wood to rot or burn and metals to corrode.

Control of corrosion is dependent upon maintaining a separation between susceptible alloys and the corrosive environment. This separation is accomplished in various ways. A good intact coat of paint provides almost all of the corrosion protection on naval aircraft. Sealants are used at seams and joints to prevent entry of moisture into the aircraft; preservatives are used on unpainted areas of working parts; and shrouds, covers, caps, and other mechanical equipment provide varying degrees of protection from corrosive media. None of these however, provide 100 percent protection in the long run—paint is subject to oxidation and decay through weathering; sealants may work out by vibration or else be eroded by rain and windblast. Preservatives at best offer only temporary protection when used on operating aircraft and the mechanical coverings are subject to improper installation and neglect. Control of corrosion properly begins with an understanding of the causes and nature



AM.49

Figure 11-1.–Simplified corrosion cell.

of this phenomenon. Corrosion is caused by electrochemical or direct chemical reaction of a metal with other elements. In the direct chemical attack, the reaction is similar to that which occurs when acid is applied to bare metal. Corrosion in its most familiar form is a reaction between metal and water and is electrochemical in nature.

In the electrochemical attack, metals of different electrical potential are involved and they need not be in direct contact. When one metal contains positively charged ions and the other negatively charged ions and an electrical conductor is bridged between them, current with flow as in the discharge of a dry cell battery. In electrochemical corrosion the conductor bridge may be any foreign material such as water, dirt, grease, or any debris that is capable of acting as an electrolyte. The presence of salt in any of the foregoing mediums tends to accelerate the current flow and hence speed the rate of corrosive attack.

Once the electrical couple is made, the electron flow is established in the direction of the negatively charged metal (cathode), and the positively charged metal (anode) is eventually destroyed. All preventive measures taken with respect to corrosion control are designed primarily to avoid the establishment of the electrical circuit, or secondly, to remove it as soon as possible after establishment before serious damage can result. Figure 11-1 illustrates the electron flow in a corrosion environment (electrolyte) resulting in destruction of the anodic area. Note that the surface of a metal, especially alloys of the metal, may contain anodic and cathodic areas due to impurities or alloying constituents which have different potentials than the base metal.

Electrochemical attack is evidence in several forms, depending upon the metal involved, its size and shape, its specific function, atmospheric conditions, and the type of corrosion-producing agent (electrolyte) present. There are many forms of metal deterioration resulting from electrochemical attack about which a great deal is known. But despite extensive research and experimentation, there is still much to be learned about other, more complex and subtle forms. Descriptions are provided later in this chapter for the more common forms of corrosion found on airframe structures.

Since there are so many factors which contribute to the process of corrosion, selection of materials by the aircraft manufacturer must be made with weight versus strength as a primary consideration and corrosion properties as a secondary consideration. In the interest of aerodyanmic efficiency, even the number of drain holes is limited until accumulated operational data indicates a greater drain requirement. Close attention during aircraft design and production is also given to heat treating and annealing procedures, protective coatings, choice and application of moisture barrier materials, dissimilar metals contact, and access doors and plates. In other words, every logical precaution is taken by the aircraft manufacturers to inhibit the onset and spread of corrosive attack.

There are many factors that affect the type, speed, cause, and the seriousness of metal corrosion. Some of these corrosion factors can be controlled; others cannot. Preventive maintenance factors such as inspection, cleaning, and painting and preservation are within the control of the operating squadron. They offer the most positive means of corrosion deterrence.

The electrochemical reaction which causes metal to corrode is a much more serious factor under wet, humid conditions. The salt in sea water and the salt in the air is the greatest single cause of aircraft corrosion. Hot climates speed the corrosion process because the electrochemical reaction develops fastest in a warm solution, and warm moisture in the air is usually sufficient to start corrosion if the metals are uncoated. As would be expected, hot dry climates usually provide relief from constant corrosion problems. Extremely cold climates produce corrosion problems if a salt atmosphere is present. Melting snow or ice provides the necessary water to begin the electrochemical reaction.

Thick structural sections are subject to corrosive attack because of possible variations in their composition, particularly if they were heat treated during fabrication. Similarly, when large sections are machined or cut out after heat treatment, thinner sections have different physical characteristics than the thicker areas. In most cases, different in physical characteristics provides enough difference in electrical potential to render the piece highly susceptible to corrosion. Another corrosion factor regarding size of materials lies in the area relationship between dissimilar metals. When two dissimilar metals are used where possible contact may develop, if the more active metal is small, compared to the less active one, corrosive attack will be severe and extensive if the insulation should fail. If the area of the less active metal is small compared to the other, anodic attack is relatively slight. Figure 11-2 illustrates this factor.

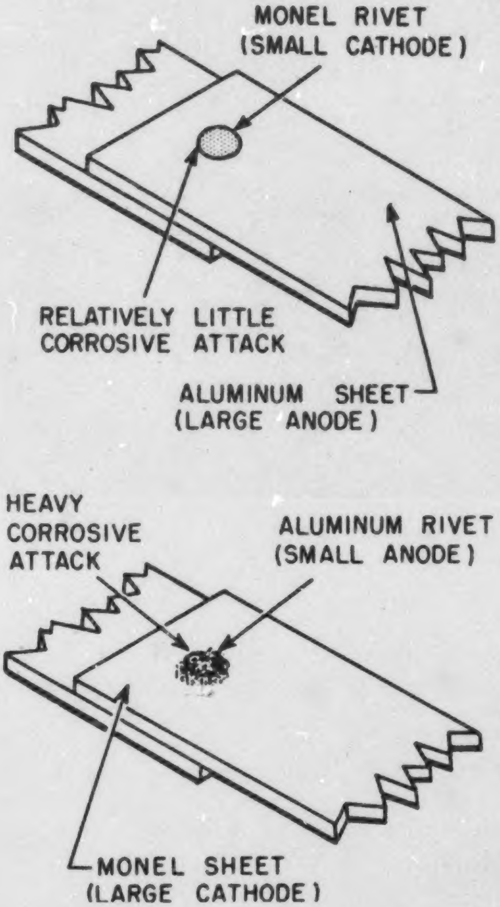


Figure 11-2.—Effects of area relationships in dissimilar metal contacts.

One of the biggest problems in corrosion control is in knowing what materials to use, where to find them, and the limitations applicable to their use. Materials used should be those covered and controlled by military specifications, preferably those authorized specifically for use on aircraft. Corrosion control information pertaining to materials, methods, and techniques is scattered throughout many directives and instructions, and this information is constantly being revised as better chemicals and protective methods are developed. The following is a list of sources of information that should be readily available for reference in every unit's technical library or in the airframes shop.

1. Aircraft Cleaning and Corrosion Control for Organizational and Intermediate Maintenance Levels, NavAir 01-1A-509.
2. Preservation of Naval Aircraft, NavAir 15-01-500.
3. Chart—Cleaning Materials for Naval Air Systems—Maintenance and Overhaul Operations, NavAir 07-1-503.
4. Chart—Corrosion Preventive Compounds used by Naval Air Systems Command, NavAir 01-1A-518.
5. Corrosion Control, Cleaning, Painting, and Decontamination. (One volume of the Maintenance Instructions Manuals for all late model aircraft is on these subjects.)

6. Periodic Maintenance Requirements Cards (as applicable).

PREVENTIVE MAINTENANCE

"An ounce of prevention is worth a pound of cure." Where corrosion prevention on naval aircraft is concerned the foregoing cliche is a ridiculous understatement. Compared with the cost of some late model aircraft which runs into millions of dollars the cost of corrosion prevention is a mere pittance. Preventive maintenance is a powerful tool which can be used to effectively control even the most difficult corrosion problems.

Most corrosion prevention programs are adjusted by the operating activity to meet severe conditions aboard ship and then decreased in scope when the aircraft is returned to the relatively mild conditions prevailing ashore. When regular corrosion preventive maintenance must be neglected in emergencies due to tactical operating requirements, a period of intensive care should follow in order to bring the aircraft back up to standard.

Preventive measures most commonly taken with respect to corrosion require the aircraft to be kept as clean as possible, all surface finishes intact, correct and timely use of covers and shrouds, periodic lubrication, and the application of preservatives where required. Years of experience have proven the need for such measures if the aircraft are to remain airworthy.

Where corrosion preventive maintenance is neglected, aircraft soon become unsafe to fly. Squadrons with the best corrosion preventive programs are likely to have the best safety records, most utilization of aircraft, and lowest operating costs.

SURFACE MAINTENANCE

Surface maintenance includes regular cleaning of the aircraft as well as touchup of protective paint coatings. Since paint touchup is accomplished after removal of corrosion, coverage on this subject is included under the heading, Corrosion Elimination, later in this chapter. This does not imply that touchup of damaged paint should not be done unless corrosion is present. Touchup of new damage to paint finishes will prevent corrosion from starting there.

The cleaning of aircraft is an important function in retaining the aerodynamic efficiency and safety of aircraft. In keeping with this importance, acceptable materials, methods, and procedures for use in aircraft maintenance cleaning are prescribed in current directives and must be used. Instances of serious damage have resulted to exterior and interior of aircraft due to the lack of correct information regarding materials and equipment and their use. Shipboard procedures are not necessarily the same as procedures ashore, but the same materials are available and comparable results are accomplished, although different application methods may be necessary.

How often an aircraft should be cleaned depends on the type of aircraft and the environment in which it has been operating. It is important that the aircraft be kept in a clean condition and repeated cleaning should be accomplished as often as necessary. The necessity for cleaning is indicated whenever there is any appreciable amount of soil accumulation within exhaust track areas; by the presence of salt deposits or other contaminants such as stack gases; by evidence of paint surface deterioration such as softening, flaking, or peeling; and by the presence of excessive oil or exhaust deposits or spilled electrolyte and deposits around battery areas. Cleaning is always mandatory immediately after exposure to fire extinguishing materials, after exposure to adverse weather conditions and salt spray, after the aircraft has been parked near seawalls during high wind conditions, after low level flight, and after repairs or service which has left stains, smudges, or other gross evidence of maintenance. A daily cleaning or wipedown is required on all exposed unpainted surfaces such as struts, actuating cylinder rods, etc.

Aircraft must be thoroughly cleaned before being placed in storage and should also receive a thorough cleaning at the time of depreservation. Unpainted aircraft are cleaned and also polished at frequent intervals. Aboard ship, cleaning and removal of salt deposits are necessary as soon as possible to prevent corrosion.

Components which are critically loaded

(designed with minimum safety margins to conserve size and weight) such as helicopter rotor parts, and components and parts which are exposed to corrosive environments, such as engine exhaust gas, acid, or rocket blast, are cleaned as often as possible to minimize exposure to these corrosive agents.

NOTE: Lubrication and preservation of exposed components are necessary to displace any of the cleaning solution entrapped during the cleaning operation.

Materials

Only NavAir specification cleaning materials may be used on aircraft. Navy specification cleaning materials are made up and compounded to accomplish definite results and are made available only after complete testing and actual field acceptance. All specification materials are inspected and tested before acceptance and delivery to the supply activities. Cleaning agents commonly used by Organizational and Intermediate maintenance activities are included in the following categories.

SOLVENTS.–Solvents are liquids which dissolve other substances. There are a great number of different solvents, but for cleaning purposes, organic solvents are most often used. Some solvents are chlorinated. When solvents contain more than 24 percent by volume of chlorinated materials they must be kept in specially marked containers and care must be taken to insure that equipment in which these solvents are used are designed and operated as to prevent the escape of such solvents, as a liquid or vapor, into the workroom.

All personnel occupied with or working near chlorinated solvents should be particularly careful to avoid breathing the vapors. While the vapors from some solvents are more toxic than others, prolonged breathing of the fumes can be injurious to health.

In addition to the breathing hazard associated with solvents, they also present varying degrees of fire and explosion hazards, depending upon the material. It is considered that solvent cleaners having a flashpoint greater than 105° F are relatively safe. Those having flashpoints below 105° F require explosion proofing of equipment and other special precautions when using them. (The flashpoint is the temperature at which the first flash from the material is seen, as an open flame is passed back and forth over a sample of flammable liquid being heated in a cup.)

Another hazard associated with solvents, and to a certain extent with all cleaning materials, is the effect on the surface or material being cleaned. Some solvents will deteriorate rubber, synthetic rubber, asphaltic coverings, etc. This is such an important consideration that it must always be taken into account when selecting cleaning materials. It may do a good job in removing dirt, grease, oil, exhaust gas deposits, etc., but may also damage the object being cleaned or soften and ruin otherwise good paint coatings.

Solvent, Drycleaning.–This material is a petroleum distillate commonly used in aircraft cleaning. It is furnished in two types, I and II. Type I material, commonly known as Stoddard solvent, has a flashpoint slightly above 100° F. Type II has a higher (safer) flashpoint and is intended for shipboard use.

In naval aviation maintenance, Stoddard solvent (type I) is used as a general all-purpose cleaner for metals, painted surfaces, and fabrics. It may be applied by spraying, brushing, dipping, and wiping. This material is preferable to kerosene for all cleaning purposes because kerosene leaves a light oily film on the surface.

Mineral Spirits.–This is another liquid petroleum distillate which is used as an all-purpose cleaner for metal and painted surfaces and as a diluting material for emulsion compounds, but is not recommended for fabrics. Like Stoddard solvent, it may be applied by spraying, brushing, dipping, and wiping.

Aliphatic Naphtha.–This is an aliphatic hydrocarbon product used as an alternate compound for cleaning acrylics and for general cleaning purposes that require fast evaporation and no remaining film residue. It may be applied by dipping and wiping. Saturated surfaces must not be rubbed vigorously, as it is a highly volatile and flammable solvent with a flashpoint below 80° F. Avoid prolonged breathing and skin contact. Use in well-ventilated areas only.

Aromatic Naphtha.–This is a petroleum aromatic distillate. This naphtha is a bare-metal cleaner and is also used for cleaning primer coats before applying lacquer. It will remove oil, grease, and light soils. It is also highly flammable and reasonably toxic. Avoid prolonged breathing and skin contact. CAUTION: Do not use aromatic naphtha on acrylic surfaces as it will cause crazing (fine surface cracks).

Safety Solvent.–Methyl chloroform is intended for use where a high flashpoint and less toxic solvent than carbon tetrachloride is required. It is used for general cleaning and grease removal of assembled and disassembled engine components in addition to spot cleaning, but should not be used on painted surfaces. Safety Solvent is not suitable for oxygen systems although it may be used for other cleaning in ultrasonic cleaning devices. It may also be applied by wiping, scrubbing, or booth spraying. The term Safety Solvent is derived from the high flashpoint. Many later issue maintenance manuals label safety solvent as Trichlorethane 1,1,1.

Methyl Ethyl Ketone (MEK).–This material is used as a cleaner for bare-metal surfaces. It will not mix to any great extent with water but is a diluent for lacquers. It is applied with wiping cloths or soft bristle brushes over small areas at a time.

WATER EMULSION CLEANERS.–Emulsion cleaners tend to disperse contaminants into tiny droplets which are held in suspension in the cleaner until they are flushed from the surface. Water emulsion compound conforming to MIL-C-22543 contains emulsifying agents, coupling agents, detergents, solvents, corrosion inhibitors, and water. It is intended for use on painted and unpainted surfaces in heavy duty cleaning operations where milder specification materials of lower detergency would not be effective. It is used in varying concentrations, depending on the condition of the surface. A concentration of 1 part compound to 4 parts water, by volume, is recommended for heavier soiled surfaces. For mildly soiled surfaces, the concentration is changed to 1 part compound to 9 parts water, by volume. Starting at the bottom of the area being cleaned, apply the mixed solution by spraying or brushing to avoid streaking. Loosen surface soils by a mild brushing or mopping and follow with a thorough fresh water rinse. The automatic shutoff type water spray nozzle is best for rinsing. It gives hand control from a light mist or fogging spray to a full spray with high-pressure water.

ALKALINE WATERBASE CLEANING COMPOUND.–This compound is similar to the water emulsion cleaner. It is a general purpose cleaner used to remove light to moderate soils. It is mixed in 1 part compound to 9 parts water for light soils and 1 part compound to 3 parts water for removing medium soils. It may be applied to the surface by mopping, wiping, spray equipment, or foam producing equipment. It is safe for use on fabrics, leather, glass, ceramics, and transparent plastics. Follow the previously described procedure for washing the aircraft and rinse thoroughly with fresh water before the compound dries to prevent streaking.

SOLVENT EMULSION CLEANERS.–This cleaner, conforming to Specification P-C-444, is intended for heavy duty cleaning and should be used with caution around painted surfaces as it will soften paint if in contact with the paint finish very long. It will remove corrosion preventive coatings and should not be used on parts thus protected unless it is desired that such protective coatings be removed. For heavy cleaning, the cleaning compound is mixed in a concentration of 1 part compound to 4 parts of dry-cleaning solvent (Stoddard solvent) or mineral spirits. For lighter duty use, it can be mixed at a 1 to 9 ratio.

WATERLESS CLEANER.–This compound is intended for use on painted and unpainted aircraft surfaces in heavy duty cleaning operations where water for rinsing is not readily available or where freezing temperatures do not permit the use of water. It is relatively nontoxic, noncorrosive, nonflowing gel or cream, and its detergent properties enable it to be used as an effective agent for the removal of grease, tar, wax, carbon deposits, and exhaust stains. It should not be applied to canopies or other acrylic plastic surfaces. It is safe for use as a waterless hand cleaner.

MECHANICAL CLEANING MATERIALS.–Mechanical cleaning materials such as abrasive papers, polishing compounds, polishing cloths, wools, wadding, etc., are available in the supply system for use as needed. However, their use must be in accordance with the cleaning procedures outlined in NavAir 01-1A-509, the specific aircraft Maintenance Instructions Manual, and directions supplied with the material being used if damage to finishes and surfaces is to be avoided. In cases of conflicting information, NavAir 01-1A-509 will always take precedence.

Aluminum Oxide Paper.–Aluminum oxide paper (300 grit or finer) is available in several forms and is safe to use on most surfaces since it does not contain sharp or needle-like abrasives which can embed themselves in the base metal being cleaned or in the protective coating being maintained. The use of carborundum (silicon carbide) papers as a substitute for aluminum oxide paper should be avoided. The grain structure of carborundum is sharp, and the material is so hard that individual grains can penetrate and bury themselves even in steel surfaces.

Powdered Pumice.–This material is a mild abrasive cleaner. The pumice is used as a slurry with water and is applied to the surface with clean rags and bristle brushes.

Impregnated Cotton Wadding.–Cotton which has been impregnated with a cleaning material is used for the removal of exhaust gas stains and for polishing corroded aluminum surfaces. It is also used on other metal surfaces to produce a high reflectance.

Aluminum Metal Polish.–Aluminum metal polish is used to produce a high-luster, long-lasting polish on unpainted aluminum-clad surfaces. It is not used on anodized surfaces as it will remove the oxide coat.

Aluminum Wool.–Three grades of aluminum wool–coarse, medium, and fine–are stocked for general abrasive cleaning of aluminum surfaces.

Lacquer Rubbing Compound, Type III.–For the removal of engine exhaust residues and minor oxidation, lacquer rubbing compound, Type III, may be used. Heavy rubbing over rivet heads or edges where protective coatings may be thin should be avoided as the coverings may be damaged most easily at these points.

Cleaning Equipment

The cleaning of aircraft not only requires the use of correct cleaning materials, but also the use of properly maintained equipment to produce efficient and satisfactory results. A specific cleaning area should be prepared and equipped for performing cleaning operations.

The choice of equipment depends on several factors, such as the amount of cleaning that is regularly performed, the type of aircraft that is being cleaned, the location of the activity, and the availability of facilities such as air pressure, water, and electricity.

Several specialized items of equipment are available for cleaning aircraft. These include pressure type tank sprayers, a variety of spray guns and nozzles, high-pressure cleaning machines, and industrial type vacuum cleaners.

One of the latest devices for faster and economical cleaning of aircraft is a swivel type conformable applicator cleaning kit developed by the 3M Company. Officially designated Scotch-Brite Conformable Applicator Cleaning Kit No. 251, it is designed to clean aircraft exteriors several times faster than using cotton mops or bristle brushes.

The applicator head of the cleaning kit is curved and flexible to conform readily to convex and concave aircraft exteriors. A swivel joint on the back of the applicator head provides further flexibility. The 5 x 7 inch Scotch Brite cleaning and polishing pad attaches easily to the applicator head and provides a more aggressive and efficient scrubbing medium than bristle fibers. It can be used without fear of scratching aluminum or painted surfaces.

The swivel and applicator head are attached to a standard brush handle. The excellent conformability of the applicator allows easier application of a constant scrubbing pressure on curved skin panels and eliminates the need for a maintenance stand to keep brushes in maximum contact with the surface.

Some larger shore activities maintain a self-contained vehicle Flight Line Maintenance Master for use of all tenant activities. The Flight Line Maintenance Master is self-propelled and self-contained. It provides a heated soap solution with its own water system. It has a 1,000-gallon capacity and is equipped with an extendable boom to accommodate cleaning of high horizontal and vertical stabilizers.

The cleaning solution is sprayed at high pressure from the boom or ground level positions or both positions simultaneously. Control of the boom and cleaning solution can be made from the boom or the vehicle cab. The maneuverability of the vehicle makes it extremely efficient in cleaning all exterior aircraft surfaces. Brushing of surfaces can be easily accomplished by the boom operator. The ground hose is equipped with a crank rewind and is 50 feet long. The boom is equipped with floodlights to accomodate nighttime use of the vehicle. As with other support equipment, the maintenance master should only be operated by qualified and licensed personnel. In some cases specialized equipment must be manufactured locally by the activity, otherwise it is procured through regular supply channels.

In addition to the specialized equipment mentioned above, other items such as hoses, brushes, sponges, and wiping clothes are required for aircraft cleaning. These items are procured through supply.

Items of personal protection such as rubber gloves, rubber boots, goggles, and aprons should be worn when necessary to protect clothing, skin, and eyes from fumes and splashing of caustic materials.

Cleaning Methods and Procedures

The first step in cleaning the aircraft is selecting the proper cleaning agent for the method of cleaning to be used. The recommended type cleaning agent for each method, including instructions and precautions to be observed in their use, may be found in NavAir 01-1A-509 and the applicable Maintenance Instructions Manual for the type of aircraft being cleaned.

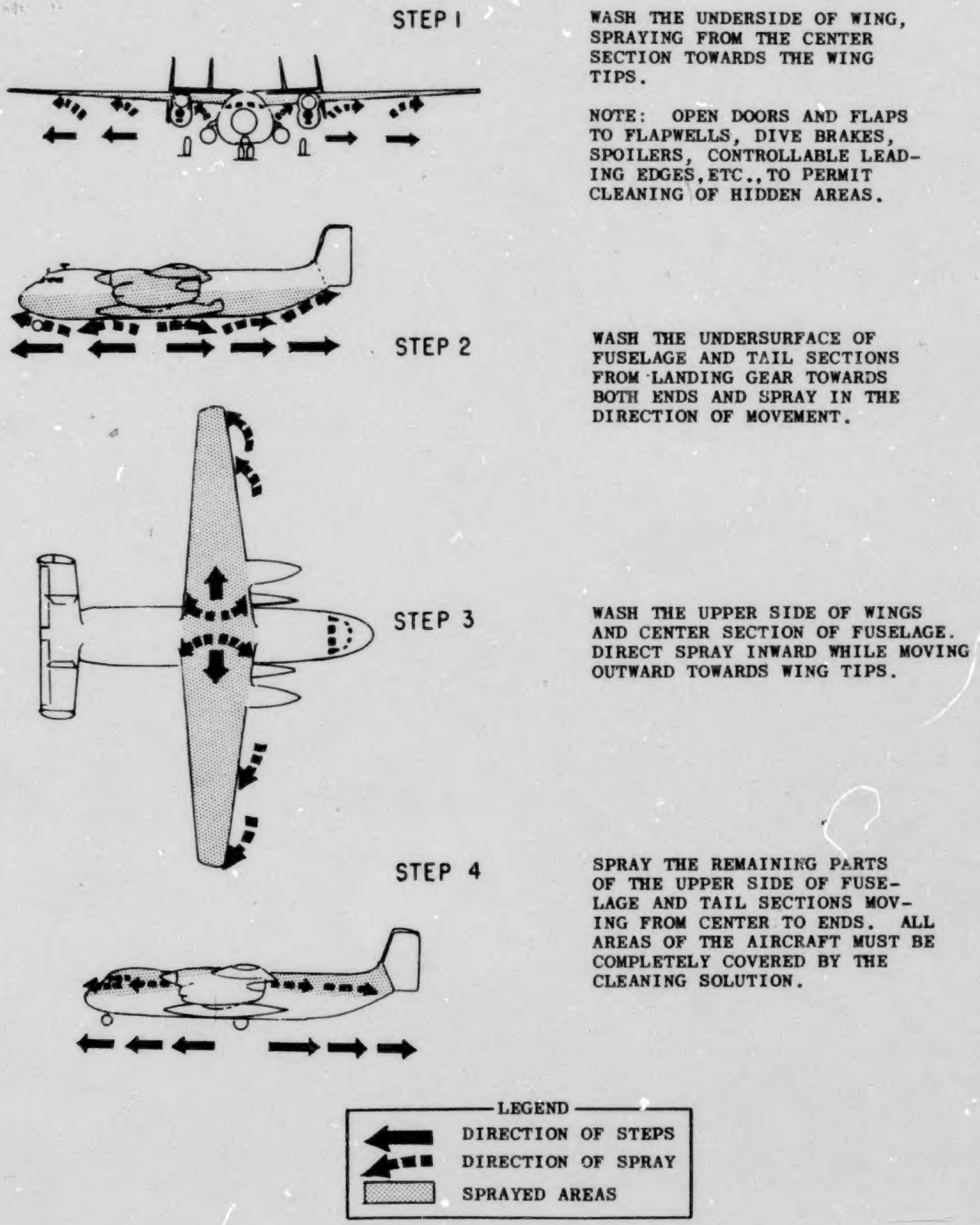
The next step is the preparation of the aircraft for cleaning. Ground the aircraft to the deck after spotting it in a cool place if possible. If the aircraft has been heated while parked in the sun or areas of the aircraft are heated as a result of operations, it should be cooled before the start of cleaning by the use of fresh water washdown. Many cleaning materials will clean faster at elevated temperatures, but the risk of damage to paint, rubber, and plastic surfaces is increased by the cleaners which are concentrated by the rapid solvent evaporation caused by the high temperatures. Static electricity generated by the cleaning operation will be dissipated through the ground wire. After securing all the obvious openings such as canopies and access panels, further secure the aircraft against entry of water and cleaning compounds as necessary. Mask or otherwise cover all equipment or components that can be damaged by moisture or the cleaning agent being used.

WATER RINSE CLEANING.–The water rinse method is recommended as the most efficient and satisfactory method of cleaning aircraft when they are only lightly contaminated with loosely adhering soils and water soluble corrosion products. The aricraft is prepared as previously outlined, and all materials and equipment that will be required during the cleaning are ascertained to be on hand and ready for use. The proper washing procedure to insure complete coverage is illustrated and described in figure 11-3. Apply water by progressing upward and outward, scrubbing briskly with a long handled fiber cleaning brush as necessary while the water is being applied. Do not scrub a dried surface. After scrubbing, rinse the surface from the top downward with a high-pressure stream of water until all the water soluble residues and loosened soils have been completely flushed off the aircraft.

WATER EMULSION CLEANING.–The emulsion cleaning method is used to clean aircraft contaminated with oil, grease, or other foreign matter which cannot be easily removed by other methods. The aircraft is prepared in the same manner as it was for the water rinse method.

Wet down the surface to be cleaned with fresh water. Apply a concentrated solution of 1 part emulsion compound cleaner to 4 parts of water to the heavily soiled areas, such as engine nacelles, landing gear assemblies, or other special areas that will require such a strong solution. Scrub these areas and allow the concentrated solution to remain on the surface. Limit the size of the area being cleaned to that size which can be easily cleaned while keeping the surface wet.

Next apply a diluted solution of emulsion compound and water, mixed to a ratio of 1 part emulsion compound to 9 parts water, to the entire surface to be cleaned including those areas previously covered with the concentrated solution. Scrub the surfaces thoroughly and allow the solution to remain on the surfaces 3-5 minutes before rinsing. Rinse from the top downward until all soils have been removed. If a high-pressure stream of water is used for rinsing, hold the nozzle at an angle and a reasonable distance from the surface being sprayed.



STEP 1

WASH THE UNDERSIDE OF WING, SPRAYING FROM THE CENTER SECTION TOWARDS THE WING TIPS.

NOTE: OPEN DOORS AND FLAPS TO FLAPWELLS, DIVE BRAKES, SPOILERS, CONTROLLABLE LEADING EDGES, ETC., TO PERMIT CLEANING OF HIDDEN AREAS.

STEP 2

WASH THE UNDERSURFACE OF FUSELAGE AND TAIL SECTIONS FROM LANDING GEAR TOWARDS BOTH ENDS AND SPRAY IN THE DIRECTION OF MOVEMENT.

STEP 3

WASH THE UPPER SIDE OF WINGS AND CENTER SECTION OF FUSELAGE. DIRECT SPRAY INWARD WHILE MOVING OUTWARD TOWARDS WING TIPS.

STEP 4

SPRAY THE REMAINING PARTS OF THE UPPER SIDE OF FUSELAGE AND TAIL SECTIONS MOVING FROM CENTER TO ENDS. ALL AREAS OF THE AIRCRAFT MUST BE COMPLETELY COVERED BY THE CLEANING SOLUTION.

LEGEND

← DIRECTION OF STEPS

⇠ DIRECTION OF SPRAY

▨ SPRAYED AREAS

AM.51

Figure 11-3.—Aircraft washing procedures.

If any areas are still not clean, repeat the operation in those areas only. After rinsing, the aircraft may be dried with a clean sponge or cloths to insure against streaking that could be caused by emulsion cleaning. Normally, if the aircraft is thoroughly rinsed, streaking will be held to a minimum.

SOLVENT-EMULSION CLEANING.–Solvent-emulsion cleaning is intended for cleaning heavily soiled unpainted surfaces and parts and for use in removing corrosion preventive coatings. The cleaning compound is mixed in a concentration of 1 part compound to 9 parts of drycleaning solvent or mineral spirits. The solution is applied to a water-free surface, otherwise the water would lessen the solvent action. Since this cleaner will remove thick preservative materials, it should be used with care to prevent unwanted removal of such coatings.

The solution is applied by brush or with a high-pressure spray using a nozzle that gives a coarse fan-shaped spray. Scrub the surface with a brush as the solution is being applied. Allow the solution to remain on the surface long enough to loosen the soil without drying. Reapply and rescrub the more difficult soiled areas as necessary. Rinse thoroughly, using a large volume of fresh water to remove all loose soils and cleaning compound.

SPOT CLEANING.–Light oily soiled surfaces may be spot cleaned by wiping these areas with a dry-cleaning solvent. The solvent is applied with a saturated wiping cloth. Brush or wipe the surface as necessary then wipe clean with a dry cloth, removing the solvent residue and loosened soil. The solvent wipe may leave a light residue which may be removed with soap and water followed by fresh water rinsing.

WARNING: Drycleaning solvent should not be used in oxygen areas or around oxygen equipment. The solvent is not oxygen compatible and will cause explosion and/or fire.

WATERLESS WIPEDOWN.–When water is not available, heavy soils and operational films may be removed by using waterless cleaner. The cleaner is applied by dipping a dampened cloth into the creamlike waterless cleaning material and then spreading the material thinly over the area to be cleaned. Scrub the surface until the soil and cleaner become intermixed or emulsified. Allow the material to remain on the surface approximately 10 minutes; scrub and wipe off thoroughly with a clean wiping cloth. Make sure all soils and cleaning material are removed, exercising special care around fasteners and unsealed areas. In freezing weather a dry applicator should be used in lieu of a dampened one.

Post-Cleaning Requirements

Following cleaning, the aircraft should be relubricated in accordance with the Maintenance Requirements Cards. Insure that all low-point drains are open. Apply aircraft preservatives as required to those clean, exposed unpainted surfaces. The types of preservatives are discussed later in this chapter. Insure that the felt wiper washers on all hydraulic cylinders are moistened with hydraulic fluid and that all exposed strut and actuating cylinder rods are wiped down with a clean rag saturated with hydraulic fluid. Remove any damaged or loosened sealant and replace in accordance with the applicable Maintenance Instructions Manual or Structural Repair Manual.

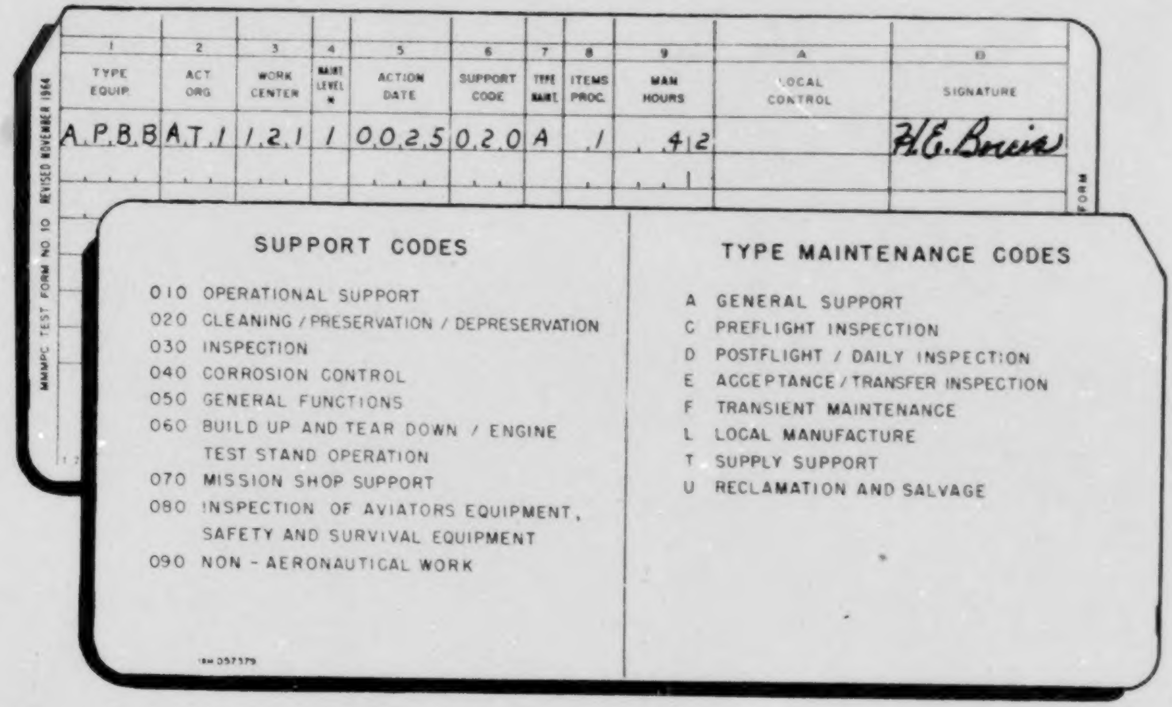
Figure 11-4 illustrates the documentation of a Support Action Form (SAF) utilized to account for the time spent cleaning an aircraft. The spaces 1 through 9 and A and B are self-explanatory and should be filled in accordingly. For detailed instructions on the SAF and its uses, consult Military Requirements for Petty Officer 3 & 2, NavPers 10056-C, or OpNav 4790.2.

NOTE: If the cleaning is done after normal working hours, on Saturday, Sunday, or declared holidays and the activity concerned is required to record manhour data, a Manhour Accounting (MHA) Card must be submitted in addition to the SAF.

USE OF COVERS AND SHROUDS

Each aircraft, when delivered by the manufacturer, is equipped with a complete set of tailored dust and protective covers. A typical set of covers is shown in figure 11-5 installed on an A-6A.

All covers and shrouds should be installed in such a manner that free drainage is assured. Do not create a bathtub which will trap and hold



MMMPC TEST FORM NO 10 REVISED NOVEMBER 1964

1	2	3	4	5	6	7	8	9	A	B
TYPE EQUIP.	ACT ORG	WORK CENTER	MAINT LEVEL	ACTION DATE	SUPPORT CODE	TYPE MAINT.	ITEMS PROC.	MAN HOURS	LOCAL CONTROL	SIGNATURE
APBB	AT1	121	1	0025	020	A	1	.42		H.E. Bouia

SUPPORT CODES

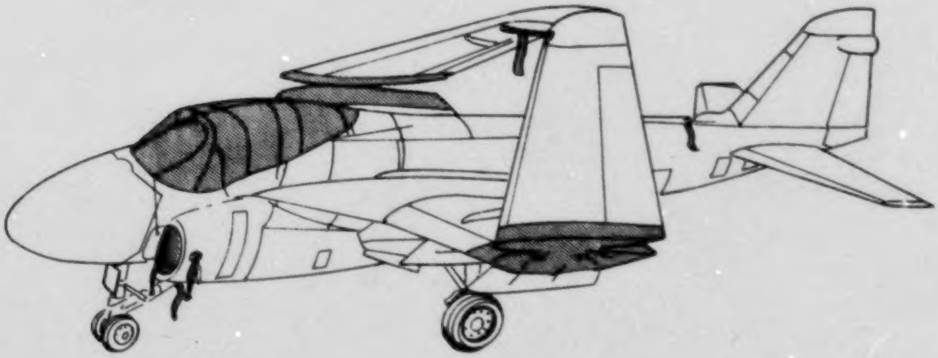
010	OPERATIONAL SUPPORT
020	CLEANING / PRESERVATION / DEPRESERVATION
030	INSPECTION
040	CORROSION CONTROL
050	GENERAL FUNCTIONS
060	BUILD UP AND TEAR DOWN / ENGINE TEST STAND OPERATION
070	MISSION SHOP SUPPORT
080	INSPECTION OF AVIATORS EQUIPMENT, SAFETY AND SURVIVAL EQUIPMENT
090	NON - AERONAUTICAL WORK

TYPE MAINTENANCE CODES

A	GENERAL SUPPORT
C	PREFLIGHT INSPECTION
D	POSTFLIGHT / DAILY INSPECTION
E	ACCEPTANCE / TRANSFER INSPECTION
F	TRANSIENT MAINTENANCE
L	LOCAL MANUFACTURE
T	SUPPLY SUPPORT
U	RECLAMATION AND SALVAGE

AM.6

Figure 11-4.—SAF documentation for cleaning aircraft.



AM.52

Figure 11-5.—A-6A dust and protective covers.

water. Shrouds or covers may also act as a greenhouse in warm weather and cause collection and condensation of moisture underneath. They should be loosened or removed and the aircraft ventilated on warm sunny days. Where protection from salt spray is required aboard carriers, the covers should be left in place and the aircraft ventilated only in good weather. Fresh water condensate will do far less damage than entrapped salt spray.

In emergencies where a regular waterproof canvas covers are not available, suitable covering and shrouding may be accomplished by using polyethylene sheet, polyethylene coated cloth, or metal foil barrier material, all of which are available in the Navy supply system. These covers should be held in place with adhesive tapes designed specifically for severe outdoor application. The tapes are also available in supply.

GROUND HANDLING REQUIREMENTS

Maintenance Instructions Manuals for aircraft usually provide brief and simple ground handling procedures which, if observed, can do much toward reducing corrosive attack. Little things like heading the aircraft into the wind and installing available covers, battens, shrouds, etc., to keep water, salt, and dirt out of areas difficult to get at and easy to overlook, can save a tremendous amount of maintenance work later.

There are many other commonsense practices which should be observed to minimize paint damage and the loss of built-in protective systems during normal ground handling of the aircraft. Much damage is done to aircraft paint films by failure to use the tiedown points provided, or by passing tiedown cables and lines over or around supporting structures in such a manner that the paint finish is worn, chipped, or broken, especially at sharp edges.

Painted aircraft surfaces will withstand a normal amount of foot traffic and abrasion by fuel hoses and air lines. However, shoe soles and fueling hoses pick up bits of sand, gravel, and metal chips and become a coarse abrasive which scratches and scuffs the protective finish to the point where it is rendered completely ineffective under shipboard operating conditions. For this reason, time should be taken to wipe or brush the sand or gravel from shoe soles before climbing on aircraft.

When removing cowling and access plates during inspections the removed hardware should not be placed on the deck to blow around and become scratched. If it is not practical to provide pads or cushioning for these components, they should at least be secured to prevent their movement. When using handtools to remove screws and quick-opening fasteners on the aircraft exterior, particular care should be taken to avoid scratching the paint. Five minutes of extra time spent in careful use of tools could save hours of paint touchup and corrosion removal work later.

AIRCRAFT PRESERVATION

The susceptibility of an aircraft to corrosion damage is greatest during those periods when the aircraft is dirty, inactive, or being shipped. Since aircraft spend more time on the ground than in the air, even in an active squadron, the need for effective protection becomes apparent.

Suitable protection against corrosive attack is achieved essentially by placing a barrier between the cleaned surface that is to be protected and any possible source of moisture. During manufacture or overhaul of the aircraft, protective barriers such as electroplate, paint, or chemical surface treatment are provided. Surfaces that cannot be so treated, and in some instances the treated surfaces themselves, must be covered with special corrosion-preventive compounds. The protection these compounds give is effective only if no moisture, dirt, or active corrosion is present on the treated surface. It is essential, therefore, that the aircraft be thoroughly clean and dry before a preservative compound is applied. It is also necessary that an unbroken film of preservatives be applied in as moisture-free an atmosphere as practicable.

Compounds alone do not provide complete protection. Tapes, barrier paper, and sealing devices must also be used to seal off the numerous openings on aircraft which, if allowed to remain open during long-time storage, would permit the entry of moisture and dirt. To provide additional protection against corrosion a complete moisture barrier is sometimes provided. Internal areas that have been sealed off are dehydrated by installing dessicants (moisture absorbents) to remove entrapped unless the cavity is protected with a vapor corrosion inhibitor. When any area cannot be sealed adequately, provision must be made for ventilation and moisture drainage.

When certain installed equipment in an aircraft is not being used regularly, its components are required to be preserved. For example, the guns of an aircraft must be cleaned after each firing. The type of oil or other protective treatment which is to be applied subsequently depends upon the anticipated period of idleness for the guns.

The requirements for the preservation of operating aircraft are of the most concern of a Third or Second Class AMS; therefore, this section emphasizes the use of preservative coatings to supplement paint films, prevent salt spray and salt water damage to operating aircraft, and minimize exposure during routine maintenance and repair.

In maintenance of aircraft surfaces, under operating conditions, preservation means supplementing the protection already present, or providing temporary protection to damaged areas, by the use of various protective coatings and barrier materials. A brief description of some of the more common materials used in aircraft preservation and readily available in Navy stock is included in the following paragraphs.

Compound, Corrosion-Preventive, Solvent Cutback

This material is familiarly known as "paralketone." It is supplied in three grades for specific application. All grades of this compound may be applied by brush, dip, or spray. They may be easily removed with Stoddard Solvent or mineral spirits. These materials are designed for cold application. Some preservative compounds must be applied hot; therefore, when intending to use one of the grades of this solvent cutback material, the specification number (MIL-C-16173) should always be verified.

Grade 1 forms a dark, hard-film, opaque cover. Its general use is limited because of the difficulty in removing aged coatings and also because of the hiding power of the material when it is applied over corroded areas. This material is used only where maximum protection against salt spray is required. Present instructions generally limit its use to seaplanes and amphibian surfaces.

Grade 2 is a soft-film, grease-type material that can be used on most operating parts. Its chief disadvantage is the fact that it may be washed off under direct exposure to salt water or may be removed by inadvertent wiping. It protects under relatively severe conditions and, given adequate maintenance and touchup as necessary, can be used for most maximum protection requirements.

Grade 4 preservative forms thin, semitransparent films through which identification data can usually be read. It also sets up relatively dry to the touch so that preserved parts may be easily handled. This grade has proved particularly effective in protecting wheel well areas and other exposed surfaces where film transparency is required and moderate protective characteristics can be tolerated. The main disadvantages of this material is that it is easily removed by water spray and requires replacement at 1-month intervals under severe exposure conditions.

Sprayable, Strippable Coating Compounds

Activities based outside of the continental United States occasionally receive aircraft from rework activities or the procuring agency via ocean surface shipment. This is especially true of helicopter and limited range fighter aircraft. These aircraft are protected during shipment with a sprayable, strippable coating system, conforming to MIL-C-6799, Type II. Type II coating systems, which are more common to maintenance personnel, are normally applied by spraying and have no harmful effects on metal, plastic, or painted surfaces. It is also useful for protecting transparent acrylic surfaces, such as canopies, against abrasion during maintenance or extended periods of down time. The type II system consists of a black base coat and a white topcoat to provide maximum heat reflection during outside exposure. Nylon ripcords with finger size loops are placed strategically about the aircraft prior to spraying to accommodate the manual stripping of coatings. When properly applied, the coatings can be easily removed. If coatings are sprayed too thin for easy removal, they can be recoated and allowed to dry. The top layer will adhere to previous layers and all layers may be manually stripped in one operation.

Corrosion-Preventive Petroleum (MIL-C-11796)

These preservatives are designed for hot application and are available in two classes–Class 1 (hard film) and Class 3 (soft film). Both consist of corrosion inhibitors in petroleum. They are removed with Stoddard Solvent or mineral spirits. Where a hard film is not necessary, Class 3 should always be used as it is easier to apply and remove yet renders the same degree of protection. Class 1 is generally used for long-time indoor protection of highly finished metal surfaces and aircraft control cables. Class 3 is used to provide protection of metal surfaces such as antifriction bearings shock-strut pistons, and other bright metal surfaces.

Class 1 must be heated to 170° to 200° F before applying by brush or dip. For brushing class 3 material, it must be between 60° and 120° F and for dipping, between 150° and 180° F.

Oil, Preservative, Hydraulic Equipment

This oil is used in the preservation of hydraulic systems and components and shock struts. This oil is similar in appearance to, but is not interchangeable with, operating hydraulic fluid, therefore before using operating hydraulic fluid (MIL-H-5606) or this preservative oil (MIL-H-6083) for any purpose the specification number should be checked to ascertain that the correct oil is being used. The preservative oil contains oxidation and rust inhibitors, viscosity improver, and antiwear agents. Hydraulic parts and components being turned in for screening and repair are flushed and drip drained with MIL-H-6083 oil prior to being forwarded.

Designed primarily for hydraulic components this oil may be used on any bare critical surface that needs protection. Operating hydraulic fluid will protect a steel panel immersed in water for only about 48 hours. The same metal panel coated with MIL-H-6083 inhibited hydraulic oil will show 100-percent protection for a period of 30 days or more.

Lubrication Oil, General Purpose, Preservative

There are several different types of lubricating oil, some of which contain preservatives. In order to be absolutely sure that the proper oil is used in a given situation, each must be identified with its specification number. The specification number for the oil discussed in this section is VV-L-800.

VV-L-800 oil was compounded for lubrication and protection of piano-wire hinges and other critical surfaces and whenever a water-displacing, low-temperature, lubricating oil is required.

VV-L-800 may be applied, as received, by brush, spray, or dip methods. It is readily removed with Stoddard solvent or mineral spirits.

Lubricating Oil, General Purpose, Low Temperature

This general purpose oil (Specification MIL-L-7870) is suitable for use anywhere that a general purpose lubricating oil with low temperature, low viscosity, and corrosive-preventive properties is required.

This oil is suitable for brush, spray, dip, or general squirt-can application. It is not necessary to remove before reoiling or for inspection.

Corrosion Preventive Compound (MIL-C-81309)

This material is a water displacing corrosion prevention compound and lubricant. It forms a thin, clear protective coating when applied by aerosol, brush, dip, or spray. It offers only short term protection so must be reapplied frequently. On exposed surfaces, protection at its best would be 7 days between applications and up to 30 days on internal surfaces which are protected from direct outside environments. It is easily removed with drycleaning solvents. It is very effective when used in the following areas: Piano-wire hinges, removable fasteners, B-nuts, linkages, bolts and nuts, ejection seat mechanisms, canopy locks, control surface hinges, electrical connectors, and microswitches.

Packaging and Barrier Materials

A minimum of packaging is necessary at the operating activity level. However, critical aircraft and engine areas require shrouding against contamination during maintenance and repair. Fuselage openings require adequate seals when cleaning and stripping materials are used. At least three acceptable barrier materials are available in Navy stock for sealing and shrouding large aircraft openings.

WATER-VAPORPROOF BARRIER MATERIAL.–This material is a laminated metal foil barrier that has good water-vapor resistance and can be used for closing of intake openings, for protection of acrylics during cleaning, and for necessary packaging of removed components and accessories being returned to overhaul. It is heat sealable with a soldering or clothes iron.

POLYETHYLENE PLASTIC FILM.–This barrier material is used for the same purposes as the metal foil barrier material and is much less expensive. It is however not puncture resistant. The plastic film is heat sealable only with special equipment.

POLYETHYLENE COATING CLOTH.–This cloth is used to a great extent in ground support equipment covers. Its use is preferred over the plastic film material for general aircraft shrouding because of its greater tear and puncture resistance.

TAPE, FEDERAL SPECIFICATION PPP-T-60, CLASS 1.–This pressure-sensitive tape is used for closure of small aircraft openings and for direct contact use on noncritical metallic surfaces. The tape has moderate water-vapor resistance, which is generally adequate for maintenance use. The main disadvantage of this tape is that some cloth-backed materials have not been preshrunk, and tape closures tend to pull loose when exposed to high humidity conditions.

PRESSURE SENSITIVE ADHESIVE TAPE.–This item is a material developed specifically for exterior preservation and sealing used in aircraft maintenance programs. It is designed for application at temperatures as low as 0° F and should perform satisfactorily over the temperature range from -65° F to 140° F. It is an excellent general purpose tape for exterior preservation and sealing operations.

CORROSION DETECTION

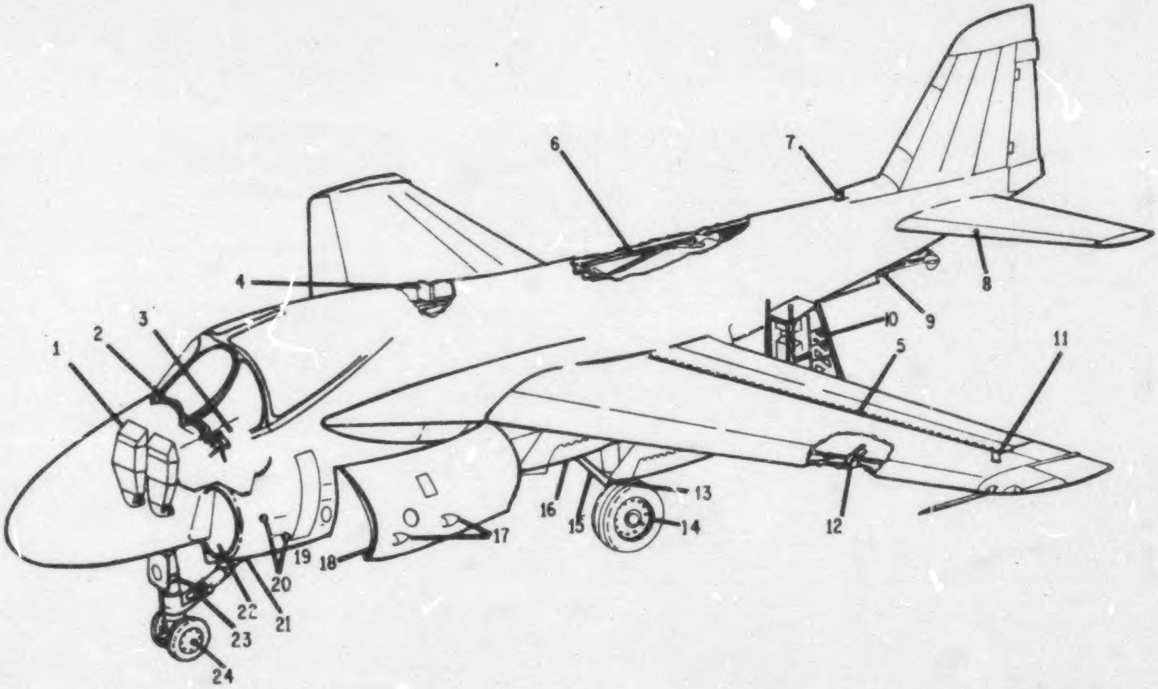
Timely detection of corrosion is essential to any corrosion control program. Of course corrosion can be detected after a part fails (if the aircraft can be recovered), but it is too late to do anything about it other than to intensify inspections of other, similar aircraft. Inspection for corrosion and deterioration should be a part of all routine inspections. There are, on every aircraft, certain areas that are more prone to corrosion than others. One should check these areas carefully. In order for the corrosion inspection to be thorough the person inspecting must know the types of corrosion likely to be found and the symptoms or appearance of each type. Sometimes corrosion is hidden and special detection methods are utilized in the search. Various aspects of corrosion detection are discussed in the following sections.

LOCATION OF CORROSION PRONE AREAS

Discussion of corrosion prone areas in this section includes trouble spots or areas that are common to all aircraft. For this reason, coverage for any given aircraft model is not necessarily complete. Figure 11-6 illustrates trouble spots applicable to a jet engine aircraft. Reference to the Periodic Maintenance Requirements Cards for specific model aircraft will enable inspections to be amplified and expanded to the necessary degree.

Exhaust Trail Areas

Both jet and reciprocating engine exhaust deposits are very corrosive. These deposits are particularly troublesome where gaps, seams, hinges, and fairings are located down the exhaust path and where the deposits may be trapped and not reached by normal cleaning methods. Inspection of these surfaces should include special attention to the areas indicated in figure 11-7. Inspection procedures should also include the removal of fairings and access panels located in the exhaust path.



1. Pallet components.
2. Rudder pedals.
3. Cockpit floor.
4. Battery compartment.
5. Piano hinges.
6. Control cables.
7. Cooling air inlet.
8. Missile rocket blast areas.
9. Exhaust areas.
10. Extensible equipment platform compartments.
11. Flap carriage cutouts.
12. Slat drives and track cutouts.
13. Exposed indicator switches.
14. Magnesium wheels.
15. Exposed rigid tubing.
16. Main wheel well.
17. Cooling air inlet.
18. Bilge areas.
19. Piano hinges.
20. Relief tube exits.
21. Exposed position indicator switches.
22. Air intake ducts and engine frontal areas.
23. Exposed rigid tubing.
24. Magnesium wheels.

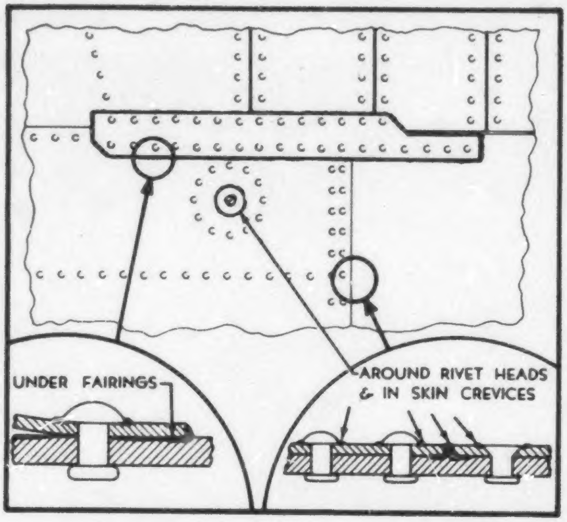
Figure 11-6.—Typical corrosion prone areas on jet engine aircraft.

JATO, Rocket, and Gun Blast Areas

Surfaces located in the path of JATO, rocket, and gun blasts are particularly subject to corrosive attack and deterioration (fig. 11-8). In addition to the corrosive effect of the gases and exhaust deposits, protective finishes are often blistered by heat, blasted away by high-velocity gases, or abraded by spent shell casings or solid particles from gun and rocket exhausts. These areas should be watched for corrosion and cleaned carefully after firing operations.

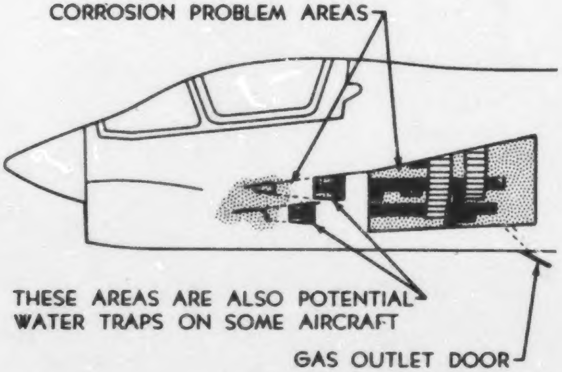
Battery Compartments and Battery Vent Openings

Fumes from battery electrolyte are difficult to contain and will spread throughout the battery compartment, vents, and even adjacent internal cavities, causing rapid, corrosive attack on unprotected surfaces. The external skin area around the vent openings should also be checked regularly for this type corrosion. Corrosion from this cause will continue to be a serious problem whenever batteries are used.



AM.54

Figure 11-7.—Exhaust trail corrosion points.



AM.55

Figure 11-8.—Gun blast area corrosion points.

Lavatories and Galleys

These areas, particularly on the deck behind lavatories, sinks, and ranges, where spilled food and waste products may accumulate, are likely trouble spots if not kept clean. Even if some contaminants are not corrosive in themselves, they may attract and hold moisture, which in turn causes corrosive attack. Inspectors should pay attention to bilge areas located under galleys and lavatories, and to personnel relief and waste disposal vents or openings on the aircraft exteriors. Human waste products are very corrosive to the common aircraft metals.

Bilge Areas

A common trouble spot on all aircraft is the bilge area. This is a natural collection point for waste hydraulic fluids, water, dirt, loose fasteners, drill shavings, and other odds and ends of debris. Oil puddles quite often mask small quantities of water which settle to the bottom and set up hidden corrosion cells. Keeping bilge areas free of all extraneous material, including oil, is the best insurance against corrosion.

Wheel Wells and Landing Gear

The wheel well area probably receives more punishement than any other area on the aircraft. It is exposed to mud, water, salt, gravel, and other flying debris from runways during flight operations and is open to salt water and salt spray when the aircraft is parked aboard ship. Due to the many complicated shapes, assemblies, and fittings in the area, complete coverage with a protective paint film is difficult to attain. Because of the heat generated from braking, preservative coatings cannot be used on jet aircraft landing gear wheels. During inspections, particular attention should be given the following:

Mangnesium wheels, especially around boltheads, lugs, and wheel web areas.

Exposed metal tubing, especially at nuts and ferrules, and under clamps and identification tapes.

Exposed position-indicator switches and other electrical equipment.

Crevices between stiffeners, ribs, and lower skin surfaces which are typical water and debris traps.

Water Entrapment Areas

Design specifications require that aircraft have drains installed in all areas where water may collect. However, in many cases these drains may not be effective, either due to improper location or because they are plugged by sealants, extraneous fasteners, dirt, grease, and debris. Daily inspection of drains should be a standard requirement, especially aboard ship.

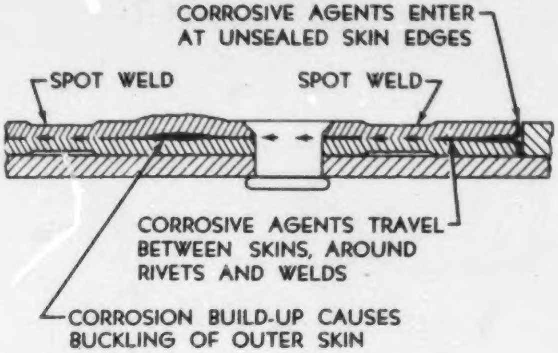
Wing Fold, Flap and Speed Brake Recesses

Flap and speed brake recesses are potential corrosion problem areas mainly because they are normally closed when on the ground. Dirt and water may collect and go unnoticed. Wing fold areas present a different problem and, like wheel wells, contain many complicated shapes and assemblies which are difficult to cover with a protective paint coating or preservative film. Wing fold areas are extremely vulnerable to salt spray when wings are folded aboard ship. Thorough inspection of this area should include a mirror check of the back sides of tubing and fittings. Also, particular attention should be paid to aluminum alloy wing lock fittings such as are used on some current aircraft models.

External Skin Areas

Most external aircraft surfaces are ordinarily covered with protective paint coatings and are readily visible or available for inspection and maintenance. Even here, certain types of configuration or combinations of materials become troublesome under shipboard operating conditions and require special attention if serious corrosion difficulties are to be avoided.

Magnesium skin, when painted over, is not visibly different from any other painted metal surface. However, those surfaces which are of magnesium are identified in the applicable Structural Repair Manual. When aircraft contain magnesium skin panels, these must be given special attention during inspections for corrosion. Some current aircraft have steel fasteners installed through magnesium skin with only protective finishes under the fastener heads or tapes over the surface for insulation. In addition, all paint coatings are thin at trimmed edges and corners. These conditions, coupled with magnesium's sensitivity to salt water attack, make up a potential corrosion problem whenever magnesium is used. Therefore, any inspection for corrosion should include the location and inspection of all magnesium skin surfaces, with special attention to edges, areas around fasteners, and cracked, chipped, or missing paint.

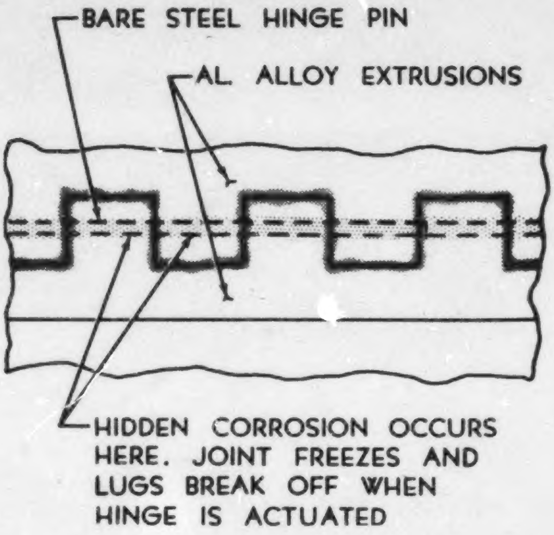

CORROSIVE AGENTS ENTER AT UNSEALED SKIN EDGES
SPOT WELD
SPOT WELD
CORROSIVE AGENTS TRAVEL BETWEEN SKINS, AROUND RIVETS AND WELDS
CORROSION BUILD-UP CAUSES BUCKLING OF OUTER SKIN

AM.56
Figure 11-9.—Spot-welded skin corrosion points.

Corrosion of spot-welded skins is chiefly the result of the entrance and entrapment of corrosive agents between the layers of metal. (See fig. 11-9.) Some of the corrosion may be caused originally by fabrication processes, but its progress to the point of skin bulging and spot-weld fracture is the direct result of moisture or salt water working its way in through open gaps and seams. This type of corrosion is first evidenced by corrosion products appearing at the crevices through which the corrosive agents entered. Corrosion may appear at other external or internal faying (closely joined) surfaces, but is usually more prevalent on external areas. More advanced corrosive attack causes skin buckling and eventual spot-weld fracture. Skin buckling in its early stages may be detected by sighting along spot-welded seams or by using a straightedge.

Piano Type Hinges

Figure 11-10 illustrates the effect of corrosion on the piano wire type hinges used on most aircraft. These are not only prime spots for corrosion due to the dissimilar metal contact between the steel pin and aluminum hinge tangs, but are also natural traps for dirt, salt, and moisture. When this type of hinge is used on access doors


BARE STEEL HINGE PIN
AL. ALLOY EXTRUSIONS
HIDDEN CORROSION OCCURS HERE. JOINT FREEZES AND LUGS BREAK OFF WHEN HINGE IS ACTUATED

AM.57

Figure 11-10.—Hinge corrosion points.

and plates which are opened only during periodic inspections, they tend to freeze in place between inspections. The inspection for corrosion of these hinges should include lubrication and actuation through several cycles to insure complete penetration of the lubricant.

APPEARANCE OF CORRODED PARTS

One of the problems involved in corrosion control is recognizing corrosion products when they occur. The following paragraphs include brief descriptions of typical corrosion product characteristics of the more common materials of aircraft construction. Photographs of typical corroded surfaces are provided in NavAir 01-1A-509 and reference to that publication will enable maintenance personnel to become more familiar with and be able to identify corrosion in its various stages.

Iron and Steel

Possibly the best known and easiest recognized of all forms of metals corrosion is the familiar reddish colored iron rust. When iron and its alloys corrode, dark iron oxide coatings usually form first, and these coatings, such as heat scale on steel sheet stock, may protect iron surfaces rather efficiently. However, if sufficient oxygen and moisture are present, the iron oxide is soon converted to hydrated ferric oxide, which is the conventional red rust.

Aluminum

Aluminum and its alloys exhibit a wide range of corrosive attack, varying from general etching of the surfaces to penetrating attacks along the internal grain boundaries of the metal. The corrosion products are seen as white to gray powdery deposits and more voluminous than the original metal. In its early stages, aluminum corrosion is evident as general etching, pitting, and roughness of the surface. The surface attack progresses quite slowly at first; however, it will be accelerated if corroding material is not given immediate attention.

Paint coatings tend to mask evidence of corrosion, but the fact that the corrosion products are more voluminous will result in corrosion showing up as blisters, flakes, chips, lumps, or other irregularities in the paint coating. Often white or gray streaks of corrosion products will become readily apparent at breaks in the paint film. Any such indications should result in further investigation to determine the extent that corrosion has progressed.

Magnesium and Its Alloys

Magnesium corrosion products are white and quite large compared to the size of the base metal being corroded. The deposits have a tendency to raise slightly and the corrosion spreads rapidly. When white puffy areas are discovered on magnesium it requires prompt attention as the corrosion may penetrate entirely through the structure in a very short time.

Copper and Copper Alloys

Copper and its alloys are generally corrosion resistant, although the products of corrosive attack on copper are commonly known. Sometimes copper or copper alloy surfaces will tranish to a dull gray-green color and the surface may still be relatively smooth. This discoloration is the result of the formation of a fine-grained, airtight copper oxide crust, called a patina. This patina in itself offers good protection for the underlying metal in ordinary situations. However, exposure of copper and copper alloys to moisture or salt spray will cause the formation of blue or green salts indicating active corrosion. These salts will form over the patina since this crust is not impervious to water (not moistureproof). Copper alloys used in aircraft generally have a cadmium-plated finish to prevent surface staining and deterioration.

Cadmium and Zinc

Cadmium, particularly, is used as a coating to protect the part to which it is applied and to provide a compatible surface when the part is in contact with other materials. The cadmium plate supplies sacrificial protection to the underlying metal because of its greater activity. That is, during the time it is protecting the base metal, the cadmium is intentionally being consumed. It functions in the same way that an active magnesium rod inserted in the water system protects the piping of a hot water heater. The cadmium becomes anodic and is attacked first, leaving the base metal free of corrosion. Zinc coatings are used for the same purpose, but to a lesser extent in aircraft. Attack is evident by white to brown to black mottling of the cadmium surfaces. These indications DO NOT indicate deterioration of the base metal. Until the characteristic colors peculiar to corrosion of the base metal appear, the cadmium is still performing its protective function. Wire brushing or removal of the mottled areas of cadmium merely reduces the amount of cadmium remaining to protect the underlying structure.

Nickel and Chromium Alloys

These metals are also used as protective agents, both in the form of electroplated coatings and as alloying constitutents with iron in stainless steels. Nickel and chromium plate protect by forming an actual physical noncorrosive barrier over the steel. Electroplated coatings, particularly chromium on steel, are somewhat porous, and corrosion eventually starts at these pores or pin holes unless a supplementary coating is applied and maintained.

Titanium

Titanium is becoming more commonly used in aircraft construction. It is a highly corrosion-resistant metal, but it may show some surface deterioration from the presence of salt deposits and other impurities, particularly at higher temperatures. Corrosion products appear as minute surface cracks. When used with other metals, insulation must be used to prevent dissimilar metal attack on the other metals.

FORMS OF CORROSION

Corrosion may occur in several forms, depending upon the metal involved, its size and shape, its specific function, atmospheric conditions, and the corrosion-producing agents present. Those described in this section are the more common forms found on aircraft structures. Corrosion has been cataloged and typed in many ways. For descriptive purposes, the types are discussed here under what is considered the most commonly accepted titles.

Direct Surface Attack

The surface effect produced by the direct reaction of the metal surface with oxygen in the air is a uniform etching of the metal. The rusting of iron and steel, the tarnishing of silver, and the general dulling of aluminum surfaces are common examples of surface attack. On aluminum surfaces if such surface attack is allowed to continue unabated, the surface will become rough and eventually frosted in appearance.

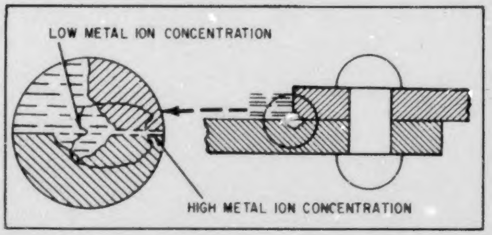
Pitting Corrosion

The most common effect of corrosion on aluminum and magnesium alloys is called pitting. It is due primarily to the variation in structure or quality between areas on the metal surface in contact with a corrosive environment.

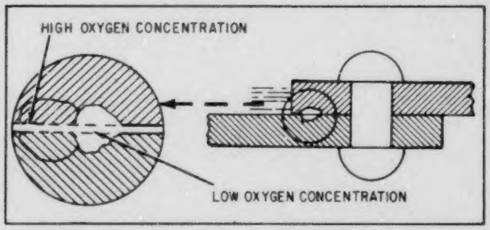
Pitting corrosion is first noticeable as a white or gray powdery deposit, similar to dust, which blotches the surface. When the superficial deposit is cleaned away, tiny pits or holes can be seen in the surface. They may appear as relatively shallow indentations or deep cavities of small diameter. Pitting may occur in any metal, but it is particularly characteristic of aluminum and magnesium.

Crevice Attack or Concentration Cell

Concentration cell corrosion is actually a form of pitting corrosion which is caused by the difference in concentration of the electrolyte or the active metal at the anode and cathode. When there is concentration differences at two different points in an entrapped pool of water or cleaning solution, anodic and cathodic areas may result, and the anodic area will be attacked. Figure 11-11 illustrates the theory of concentration cell corrosion. This type of attack is generally detected where there are crevices, scale, surface deposits, and/or stagnant water traps. This type corrosion is controlled and prevented by keeping areas cleaned, by eliminating the possibility of water accumulation, by avoiding the creation of crevices during repair work, and by elimination of any existing voids which may become water traps by the use of approved sealants and caulking compounds.



METAL ION CONCENTRATION CELL RIVETED LAP JOINT



OXYGEN CONCENTRATION CELL

AM.1128

Figure 11-11.—Concentration cell corrosion.

Intergranular Attack Including Exfoliation

All metals consist of many tiny building blocks called crystals. These crystals are sometimes called grains. The boundaries between these crystals are commonly referred to as grain boundaries. Intergranular corrosion is an attack on the grain boundaries of some alloys under specific conditions. During heat treatment, these alloys are heated to a temperature which dissolves the alloying elements. As the metal cools, these elements combine to form compounds; and if the cooling rate is slow, they form discrimininantly at the grain boundaries. These compounds differ electrochemically from the material adjacent to the grain boundaries and can be either anodic or cathodic to the adjoining areas, depending on their composition. The presence of an electrolyte will result in attack of the anodic area. This attack will generally be quite rapid and can exist without visible evidence.

As intergranular corrosion progresses to the more advanced stages, it reveals itself by lifting up the surface grain of the metal by the force of expanding corrosion products occurring at the grain boundaries just below the surface. This advanced attack is referred to as EXFOLIATION, and its recognition by corrosion personnel and immediate action to correct such serious corrosion is vital to aircraft safety. The insidious nature of such an attack can seriously weaken structural members before the volume of corrosion products accumulate on the surface and the damage becomes apparent.

Metal that has been properly heat-treated is not readily susceptible to intergranular attack; however, susceptibility can develop from localized overheating, such as could occur from welding, fire damage, etc. If the intergranular attack has not penetrated too far and sufficient structural strength remains, corrective procedures as outlined in the applicable Structural Repair

Manual could restore the aircraft to a flight status.

Whenever intergranular corrosion is evident or suspected, it should be immediately brought to the attention of senior personnel who can initiate appropriate action.

Dissimilar Metal Corrosion

Galvanic or dissimilar metal corrosion is the term applied to the accelerated corrosion of metal caused by dissimilar metal being in contact in a corrosive medium such as salt spray or water.

Dissimilar metal corrosion is usually a result of faulty design or improper maintenance practices which result in dissimilar metals coming in contact. It is usually recognizable by the presence of a buildup of corrosion at the joint between the metals. For example, aluminum and magnesium materials riveted togehter in an aircraft wing form a galvanic couple if moisture or contamination is present. When aluminum pieces are attached with steel bolts or screws, galvanic corrosion can occur around the fasteners.

Aircraft manufacturer's utilize a variety of separating materials such as plastic tape, sealant, primer, washers, lubricants, etc., to keep these metals from coming in direct contact and thus keep corrosion to a minimum. It is imperative that these separating materials remain intact or are replaced, restored, or repaired as necessary throughout the life of the aircraft.

Since some metals are more active than others, the degree of attack will depend on the relative activity of the two surfaces in contact. In any case, the more active or easily oxidized surface becomes the anode and corrodes. In plated metal the possibility of dissimilar metal corrosion becomes a factor only if there are defects in the plating, which would allow moisture penetration and subsequently the forming of a galvanic cell.

Stress Corrosion

Stress corrosion, evidenced by cracking, is caused by the simultaneous effects of tensile stress and corrosion. Stress may be internal or applied. Internal stresses are produced by nonuniform deformation during cold working, by unequal cooling from high temperatures during heat treatment, and by internal structural rearrangement involving volume changes. Stresses set up when a piece is deformed, those induced by press and shrink fits, and those in rivets and bolts are examples of internal stresses. Concealed stress is more important than design stress, especially because stress corrosion is difficult to recognize before it has overcome the design safety factor. The magnitude of the stress varies from point to point within the metal. Stresses in the neighborhood of the yield strength are generally necessary to promote stress corrosion cracking, but failures have occurred at lower stresses.

Fatigue Corrosion

Fatigue corrosion is a special kind of stress corrosion and is caused by the combined effects of corrosion and stresses applied in cycles to a part. NOTE: An example of cyclic stress is the alternating loads to which the reciprocating rod on the piston of a hydraulic, double-acting actuating cylinder is subject. During the extension stroke a compression load is applied and during the retracting or pulling stroke, a tensile or stretching load is applied. Damage from fatigue corrosion is greater than the combined damage of corrosion and cyclic stresses if the part was exposed to each separately. Fracture of a metal part due to fatigue corrosion generally occurs at a stress far below the fatigue limit in a laboratory environment, even through the amount of corrosion is unbelievably small. For this reason, protection of all parts subject to alternating stress is particularly important wherever practical, even in environments that are only mildly corrosive.

Fretting Corrosion

Fretting corrosion is a limited but highly damaging type of corrosion caused by a slight vibration, friction, or slippage between two contacting surfaces which are under stress and heavily loaded. It is usually associated with machined parts, such as the area of contact of bearing surfaces, two mating surfaces, and bolted or riveted assemblies. At least one of the surfaces must be metal. In fretting corrosion, the slipping movement at the interface on the contacting surface destroys the continuity of the protective films that may be present on the metallic surface. This action removes fine particles of the basic metal. The particles oxidize and form abrasive materials which further agitate within a confined area to produce deep pits. Such pits are usually so located as to increase the fatigue failure potential of the metal. Fretting corrosion is evidenced at an early stage by surface discoloration and by the presence of corrosion products in any lubrication present. Lubrication and securing the parts so that they are rigid are the most effective measures to prevent this type of corrosion.

Filiform Corrosion

Filiform corrosion is threadlike filaments of corrosion known as underfilm. Metals coated with organic substances, such as paint films, may undergo this type of corrosion.

Filiform corrosion occurs independent of light, metallurgical factors in the steel, and bacteria, but takes place only in relatively high humidity, 65 to 95 percent. Although the threadlike filaments are visible only under clear lacquers or varnishes, they also occur with some frequency under opaque paint films. Filiform corrosion can occur on steel, zinc, aluminum, magnesium, and chromium plated nickel.

Microbiological Corrosion

Micro-organisms contained in sea water can be introduced into fuel systems by contaminated fuel. These fungus growths attack the sealing material used on integral fuel tanks. Under certain conditions, they can cause corrosion of aluminum probably by aiding in the formation of concentration cells. Residues resulting from biological growth tend to clog fuel filters, and coat fuel capacity probes, giving erroneous fuel quantity readings.

SPECIAL DETECTION METHODS

A variety of nondestructive inspection methods may be utilized by the Aviation Structural Mechanic in detecting flaws in metal. The metals inspection techniques discussed in chapter 3 of this manual are suitable for detection of the depth of intergranular corrosion and stress corrosion cracks or other general defects in metal. Special methods to detect intergranular corrosion using ultrasonics and eddy current principles familiar to some specially trained senior Structural Mechanics have been developed. Knowledge of these more sophisticated methods is not required at the AMS 3 & 2 petty officer level. Any time there is even the slightest concern over the extent of intergranular corrosion damage or suspected damage, these specially developed methods should be conducted by qualified personnel.

CORROSION ELIMINATION

When corrosion of aircraft skin or structures has been discovered, the first step to be taken should be the safe and complete removal of the corrosion deposits or replacement of the affected part. Which of these actions to be taken depends upon the degree of corrosion, the extent of damage, the capability to repair or replace, and the availability of replacement parts. Any part which has been damaged by corrosion should be replaced if continued use is likely to result in structural failure. Areas to be treated for corrosion deposit elimination must be clean, unpainted, and free of oil and grease. Chips, burrs, flakes of residue, and surface oxides must be removed. However, care must be taken to avoid removing, at the same time, too much of the uncorroded surface metal. Corrosion deposit removal must be complete. Failure to clean any surface debris permits the corrosion process to continue even after refinishing the affected areas.

When corrosion is present, any protective paint films must first be removed to insure that the entire corroded area is visible. After the corrosion has been removed the extent of damage must be assessed. It is at this point that the determination is made to repair or replace the affected part or to perform a corrosion correction treatment. This treatment involves the neutralization of any residual corrosion materials that may remain in pits and crevices, and the restoration of permanent protective coatings and paint finishes.

PAINT REMOVAL

Paint removal operations at the Organizational and Intermediate level of maintenance are usually confined to small areas, or possibly a whole panel. In all cases, the procedures outlined in the applicable Maintenance Instructions Manual should be observed. General stripping procedures are contained in Aircraft Cleaning and Corrosion Control for Organizational and Intermediate Maintenance Levels, NavAir 01-1A-509.

Materials

All paint removers are toxic and caustic; therefore, both personnel and material safety precautions must be observed in their use. Personnel should wear eye protection, gloves, and a rubber apron.

PAINT REMOVER, SPECIFICATION MIL-R-81294.–This is a new epoxy paint remover for use in the field. This remover will strip acrylic and epoxy finishes very satisfactorily. Acrylic windows, plastic surfaces, and rubber products are adversely affected by this material. This material should not be stocked in large quantities as it ages rapidly, degrading the results of stripping action.

Additional paint removers are discussed in NavAir 01-1A-509 and NavAir 07-1-503. Each remover has a specific intended use. For example, MIL-R-81294 is for removing epoxy finishes but could be damaging to synthetic rubber, while non-flammable water soluble paint remover conforming to MIL-R-18553 is usable in contact with synthetic rubber. In all cases utilize the recommended remover that meets the requirements of the job being accomplished.

Procedures and Precautions

The stripping procedures provided in this section are general in nature. When stripping any aircraft surface, consult the applicable Maintenance Instructions Manual for the specific procedures to be used.

Stripping should be accomplished outside whenever possible. If stripping must be done in a hangar or other enclosure, adequate ventilation must be assured. CAUTION: Prior to cleaning and stripping, insure that the aircraft is properly grounded to dissipate any static electricity produced by the cleaning and stripping operations.

Using approved tapes and papers, mask all seals, joints, skin laps, bonded joints, etc., where the paint remover may contact adhesives.

Apply the stripper liberally, and completely cover the surface to a depth of 1/32 to 1/16 inch, using a bristle brush. The stripper should not be spread in a thin coat like paint, since it will not loosen paint sufficiently for removal and the remover may dry on the surface of the metal, requiring a reapplication.

Allow the stripper to remain on the surface for a sufficient length of time to wrinkle and lift the paint, which may be from 10 minutes to several hours, depending on both the temperature and humidity and the condition of the paint coat being removed. Loosened paint may be removed with fiber scrapers, bristle brushes, and rags. The surface should then be rinsed with water to remove any residual stripper.

After rinsing the area thoroughly, wipe down with rags wet with lacquer thinner or an approved solvent cleaner such as Stoddard solvent.

The next step is to remove all masking tape and carefully strip away the remaining paint it covered, using rags slightly dampened with an approved solvent cleaner such as methyl-ethyl-ketone (MEK). Use only nonmetallic scrapers to assist in removing persistent paint finishes.

CORROSION REMOVAL

After the paint has been removed from corrosion-damaged areas of metal surfaces, it is necessary to remove all corrosion deposits before an accurate assessment of damage can be made. The different corrosion removal processes required by the various aircraft metals include chemical treatments to prevent or retard future corrosive attack. These chemical treatments are discussed as a part of the corrosion removal processes in this section. Further chemical treatments are applied for the purpose of improving paint adhesion if it is determined that the corrosion damage is tolerable and the affected parts may remain in service. Prepaint treatments are discussed in a subsequent section of this chapter.

Corrosion Removal From Aluminum

There are three types of aluminum surfaces insofar as corrosion removal is concerned. They are clad, anodized, and exfoliated.

CLAD ALUMINUM SURFACES.–Pure aluminum has considerable corrosion resistance compared to aluminum alloys, but has little or no structural strength. It has been learned that an extremely thin sheet of pure aluminum laminated onto each side of an aluminum alloy sheet improves the corrosion resistance with little impairment of strength. The trade name of this aluminum laminate as originated by the Aluminum Company of America is "Alclad." From this trade name the adjective "clad" and the verb "cladding" have been derived. Not all aircraft sheet aluminum is clad, especially those alloy sheets from which small brackets, gussets, fittings, etc., are made. The pure aluminum is very soft and the fabrication processes would severely damage or destroy the clad surfaces.

To remove corrosion from clad surfaces the corroded areas should be hand polished with household abrasives such as Bon Ami or Ajax, or with a specification metal polish, MIL-P-6888. It (the specification polish) effectively removes stains and produces a high-gloss, lasting polish on unpainted clad surfaces. During the foregoing polishing operation, care must be taken to avoid unnecessary mechanical removal of the protective clad layer and the exposure of more susceptible, but stronger, aluminum alloy base.

If there is any superficial corrosion present, it should be treated by wiping down with an inhibitive material such as the Chemical Surface Films for Aluminum Alloy, available under specification MIL-C-5541. (See Chemical Surface Treatment, this chapter.)

ANODIZED ALUMINUM SURFACES.–Anodizing is the most common surface treatment of nonclad aluminum alloy surfaces. The aluminum alloy sheet or casting is the positive pole in an electrolytic bath in which chromic acid or other oxidizing agent produces an aluminum oxide film on the metal surface. Aluminum oxide is naturally protective, and anodizing merely increases the thickness and density of the natural oxide film. When this coating is damaged in service, it can only be partially restored by chemical surface treatments. Therefore, any processing of anodized surfaces, including corrosion removal, should avoid unnecessary destruction of the oxide film.

Aluminum wool, nylon webbing impregnated with aluminum oxide abrasive, or fiber bristle brushes are the approved tools for cleaning anodized surfaces. The use of steel wool, steel wire brushes, or harsh abrasive materials on any aluminum surfaces is prohibited. Producing a buffed or wire brush finish by any means is also prohibited. Otherwise, anodized surfaces are treated in much the same manner as other aluminum finishes.

EXFOLIATED SURFACES.–As previously described, exfoliation is a separation along the grain boundaries of metal and is caused by intergranular corrosion. More severe procedures must be observed when intergranular corrosion is present. The mechanical removal of all corrosion products and visible delaminated metal layers must be accomplished in order to determine the extent of destruction and to evaluate the remaining structural strength of the component. Metal scrapers, rotary files, and other necessary tools are used to assure that all corrosion products are removed and that only structurally sound aluminum remains. Inspection with a 5 to 10 power magnifying glass, or the use of dye penetrant (Chapter 3), will aid in determining if all unsound metal and corrosion products have been removed. When complete removal has been attained, any rough edges should be blended or smoothed out even though this involves the removal of more metal. Grinding, where required, can best be accomplished by using rubber base wheels into which tiny particles of aluminum oxide abrasives have been impregnated.

Chemical treatment of exposed surfaces is applied in the same manner as any other aluminum surface.

Any loss of structural strength in critical areas should be evaluated by cognizant aeronautical engineers, particularly if the damage exceeds the permissible limits established in the Structural Repair Manual for the aircraft model involved.

Corrosion Removal From Iron and Steel

The most practicable means of controlling the corrosion of steel is the complete removal of the corrosion products (rust) by mechanical means. Aluminum oxide abrasive paper or abrasive impregnated nylon webbing can be used. However, residual iron rust usually remains in small pits and crevices. Vacu-blasting with glass beads removes nearly all rust and is the preferred method.

There are approved methods for converting active iron rust to phosphates and other protective coatings; however, most of these procedures require shop installed equipment and are therefore impractical in the field. Another disadvantage of chemically inhibiting iron rust is the danger of entrapping these chemicals in installed assemblies where thorough flushing is difficult, thereby causing far more corrosion than was originally present.

HIGHLY-STRESSED STEEL SURFACES.–Any corrosion on the surface of highly stressed steel is potentially dangerous, and careful removal of the corrosion deposits is mandatory. Surface scratches or changes in the surface molecular structure due to overheating can cause sudden failure. Removal of corrosion products must be accomplished by careful processing, using mild abrasive papers such as fine grit aluminum oxide, or fine buffing compounds on cloth buffing wheels. It is essential that the steel surface not be overheated while buffing. After this careful removal of surface corrosion, protective paint finishes should be reapplied immediately.

CADMIUM PLATED SURFACES.–As stated previously, cadmium platings are still offering sacrificial protection even when they show mottling ranging from white to brown to black on their surfaces. This discoloration should never be removed for appearance sake alone. Not until the characteristic color peculiar to corrosion of the base metal appears should steps be taken.

Corrosion present should be removed by rubbing lightly with stainless steel wool. Under no circumstances should a wire brush, stainless or otherwise, be used on cadmium plates surfaces as these will remove more plating than corrosion. After the corrosion has been removed the affected area should be swabbed with a chromic acid solution and, after 30 to 60 seconds, rinsed with clean water and dried with clean cloths or low-pressure compressed air. The part is then ready for a protective paint coating.

Corrosion Removal From Magnesium

Magnesium corrosion reprotection involves the maximum removal of corrosion products, the partial restoration of surface coatings by chemical treatment, and a reapplication of protective coatings.

After cleaning the surface and stripping the paint, if any, as much of the corrosion products as possible should be broken loose and removed, using abrasive impregnated nylon webing or glass beads with the Vacu-Blast Dry Honing Machine. Steel wire brushes, carborundum abrasives, or steel cutting tools should not be used. After the corrosion has been removed, treat the surface with Specification MIL-C-5541, chemical treatment solution, as outlined in the section on Chemical Surface Treatment (this chapter); then restore the protective paint film.

If extensive removal of corrosion products from a structural casting was involved, a decision from a structural engineer may be necessary in order to evaluate the adequacy of the structural strength remaining. Structural Repair Manuals for the aircraft models involved usually include tolerance limits for dimensions of critical structural members and should be referred to if any question of safety of flight is involved.

Corrosion Removal From Titanium

Titanium surfaces that show surface deterioration from the presence of salt deposits and impurities are cleaned with Specification P-D-680 solvent (Stoddard solvent), then any corrosion is removed by hand using abrasive impregnated nylon webbing and followed by final cleaning of the surface with water emulsion cleaner solution (1 part cleaner to 9 parts water).

NOTE: The use of steel wool, iron scrapers, or steel brushes for cleaning or the removal of corrosion from titanium parts is prohibited.

MECHANICAL CORROSION REMOVAL BY BLASTING

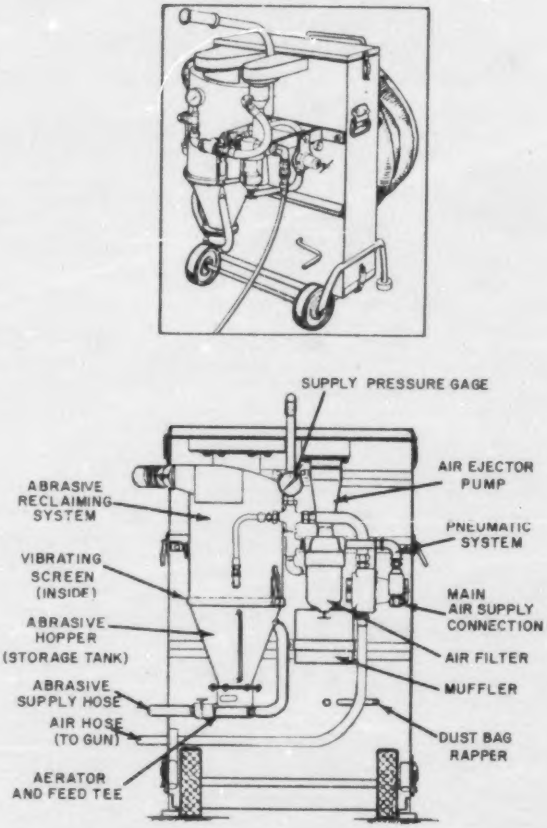
Vapor blasting, soft grit blasting, and dry vacuum blasting are the most effective mechanical methods of removing corrosion with the least removal of the metal. For use on assembled aircraft, a portable unit such as the Vacu-Blast Aero Dry Honer is the most desirable.

VACU-BLAST Aero Dry Honer

The VACU-BLAST Aero Dry Honer is a portable self-contained, lightweight unit utilizing the dry vacuum return system. (Dry honing is the only authorized blasting method of removing corrosion on assembled aircraft.) With this machine the work is more visible and metal removal can be held to closer limits. The machine is air operated and can be used in shore-based or shipboard operations.

COMPONENTS.–The dry honing machine illustrated in figure 11-12 is composed of the following principal components mounted on a two-wheel carriage assembly:

1. Pneumatic system.
2. Control and regulator vaives and gages.
3. Abrasive hopper (storage tank).
4. Aerator and feed tee.
5. Abrasive supply and return hoses.
6. Suction bypass line.
7. Blast gun assembly.
8. Gun set attachments.
9. Air ejector pump.
10. Abrasive reclaimer.
11. Dust collector.
12. Vibrating screen.



AM.59

Figure 11-12.–VACU-BLAST–Dry honing machine (back view).

A hose rack and storage compartment are provided on the front of the dry honing machine for storage of hoses, brushes, and accessories.

Pneumatic System.–The pneumatic system includes a main air supply connection at which is attached the external compressed-air supply, interconnecting tubing, and air filter with a drain cock for removal of liquid from the compressed air, and an air ejector pump that creates the necessary vacuum to return the used abrasive from the blast gun assembly to the filter bags. The dry honing machine operates satisfactorily on air pressures ranging from 80 to 100 psi and air-flows ranging from 80 to 90 cfm.

Control and Regulator Valves and Gages.–The supply pressure gage indicates the compressed-air supply pressure. The 150-pound maximum variable pressure regulator is operated to adjust the air supply to the desired pressure before entering the airhose to the blast gun assembly. This pressure is indicated on the blast pressure gage adjacent to the pressure regulator.

Abrasive Hopper (Storage Tank).–The abrasive storage tank is conical in shape to effect direction of flow of abrasive. It is removed by release of two spring clamps. The normal capacity of the storage tank is 5 pounds of abrasive material.

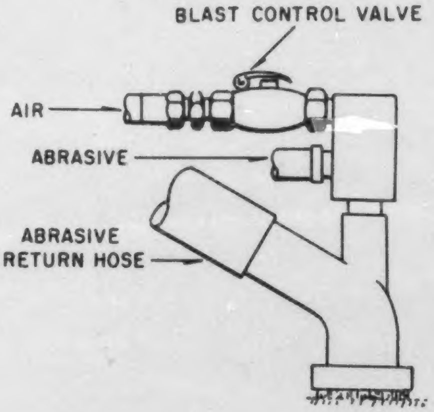
Aerator and Feed Tee.–The aerator and feed tee located at the bottom of the storage tank is designed to aerate the abrasive in the storage tank and feed is to the blast hose leading to the blast gun. The aeration is effected by mixing of air with the fine abrasive.

When the fine abrasive is aerated, debris particles which may be mixed with the abrasive, settle to the bottom of the storage tank. The abrasive is then drawn through a metering valve, from a point a short distance above the bottom of the tank, thus preventing recirculation of the debris particles. The abrasive then flows through the feed tee into the supply hose.

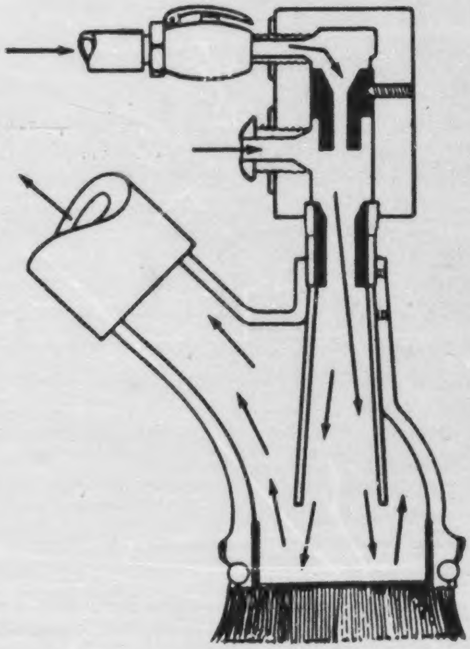
Abrasive Supply and Return Hoses.–The abrasive supply hose is a 20-foot length of 5/8-inch ID transparent plastic hose, which permits direct observation of abrasive flow. It is attached to the aerator and feed tee and conveys aerated abrasive to the blast gun assembly. The abrasive return hose is 20 feet long and returns used abrasive and debris from the blast gun assembly to the abrasive reclaiming system.

Suction Bypass Line.–The suction bypass line is designed to remove abrasive from the blast hose when the machine is shut off in order to eliminate hose surging when blasting is started again. One end of this line is connected to the feed tee opposite the blast hose connection, and the other end of the line extends up into the storage tank. This line terminates in the storage tank above the abrasive level, and the open end is protected from the abrasive by an interior baffle. When blasting stops, the exhauster remains in operation to suck air backwards through the blast gun assembly, abrasive supply hose, feed tee, and bypass line, conveying any abrasive in the hose back into the storage tank. When blasting, airflow is reversed and the bypass line insures a balanced pressure between the storage tank and the feed tee housing so that abrasive will fall freely through the feed tee into the blast hose.

Blast Gun Assembly.–The blast gun assembly (fig. 11-13) consists of a hand-held gun, blast control valve, nozzle assembly, and connections for air, abrasive supply, and return hoses. The blast gun assembly draws the abrasive material from the abrasive supply hose, accelerates the abrasive through the blast nozzle, and directs it against the workpiece. This is accomplished through the gun, which employs an eduction principle whereby compressed air is expended through an air jet to create a low pressure area in the gun housing, and by connecting the abrasive



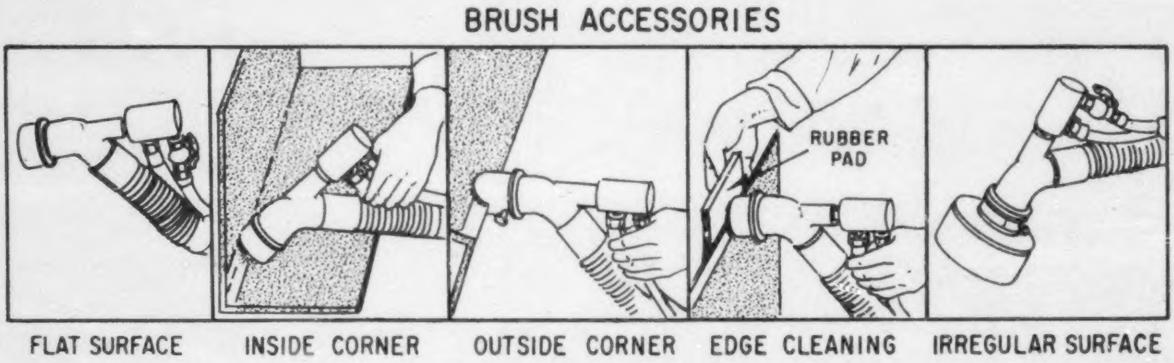
BLAST GUN ASSEMBLY



CUTAWAY VIEW

AM.60

Figure 11-13.–Blast gun assembly.



AM.61

Figure 11-14.—Gun set attachments.

supply hose to the gun housing at the point where this low pressure area is created.

Gun Set Attachments.—The three brushes and an irregular surface attachment, illustrated in figure 11-14, are provided with the dry honing machine, and permit blasting of most surfaces. Additional care must be exercised with the inside and outside corner brushes to avoid the loss of abrasive. The irregular surface attachment will conform to most irregularities.

Air Ejector Pump.—The air ejector pump creates the necessary vacuum to return the abrasive from the blast gun assembly through the return hose to the abrasive reclaimer, carrying the dust still farther to the cloth filter bags in the dust collector.

Abrasive Reclaimer.—The abrasive reclaimer is mounted directly above the abrasive storage tank and consists essentially of a cyclone separator into which abrasive and debris (from the abrasive return hose) enter. The angle at which entry is made imparts a cyclonic, or circular, action to the airstream, causing the abrasive to drop out of suspension. The conveying airstream leaves the separator through the top, carrying with it extremely fine particles of dust which are no longer usable as abrasive. The reclaimed abrasive itself drops to the bottom of the separator and then back through a vibrating screen section into the abrasive storage tank. Air and dust leaving the reclaimer cyclone pass into the cloth filter bag type dust collector onto which the reclaimer is mounted.

Dust Collector.—The dust collector consists of a number of cloth filter bags so arranged that dust laden air rising from the reclaimer cyclone is ducted to the bottom of the dust collector housing where it must pass through the cloth filter bags before being discharged through the exhauster. Filter bags are periodically cleaned by a manually operated bag-shaking mechanism to remove the accumulated dust which drops to the dust collector box for disposal.

Vibrating Screen.—The vibrating screen, incorporating a permanent magnet to remove steel particles, is located between the reclaimer cyclone and the abrasive storage tank. The screen is sufficiently fine to remove any oversize foreign particles from the abrasive. The vibrating screen is exposed for cleaning and inspection by dropping the abrasive storage tank. It is vibrated by an air-driven vibrator mounted at the center of the screen on a supporting frame, the amount of vibration being preset by an orifice in the air line.

ABRASIVE.—Although blasting equipment may use many types of abrasives, only glass beads are authorized for the removal of mild to medium corrosion from naval aircraft. Glass beads are manufactured of high grade optical crown glass, soda lime type.

OPERATING PROCEDURES.–The operating procedures listed in this section are general in nature. The dry honing machine must be used with care, and only by a qualified operator.

NOTE: A face shield must be worn at all times while operating the dry honing machine.

To operate the dry honer, fill the abrasive hopper with a full charge of the correct size abrasive material. Less than full abrasive charges may be used for touchup work or for dry honing either highly corroded or relatively small areas of steel. Contaminated abrasives should be thrown away after completion of the dry honing operation. No less than one-half charge (2 1/2 pounds) should ever be used.

After filling the machine with the correct abrasive, turn the regulator adjusting screw to the full open position, then turn on the external air supply valve. Set the pressure regulator to the desired pressure by placing the gun against a scrap piece of metal or rubber and operating the gun. The blast pressure can then be adjusted with the machine in operation.

Hold the blast gun firmly against the surface to be dry honed and press down on the blast control valve. Move the gun in a smooth pattern of overlapping strokes, advancing approximately 3/4 inch at each pass. Dwell times must be kept at the minimum necessary to produce complete corrosion removal.

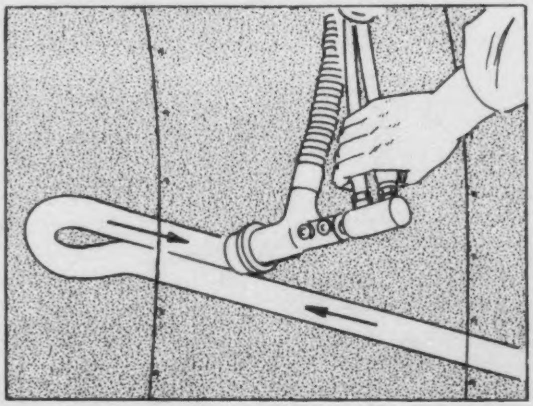
CAUTION: Excessive dwell times could result in overheating of the material and/or excessive metal removal.

Smoothest reversal of direction at the end of each pass is made by moving the brush in a small circular path as shown in figure 11-15, so that the bristles roll smoothly from one direction to the other. To prevent loss of abrasive, fully release the blast control valve each time the dry honing operation is stopped and/or before the gun is raised from the surface.

INSPECTION AND MAINTENANCE.–Certain components to the dry honing machine require inspection and maintenance at calendar or operating intervals. The two maintenance actions listed below are usually performed by the operator.

CAUTION: The main air supply must be turned off before performing any maintenance action.

Two-Hour Intervals.–At the end of each 2 hours of operation, shut off the air supply to the machine and shake down the filter bags by swinging the dust bag rapper down and sharply returning it to the normal position. Repeat this rapper action for 20 quick strokes. After shaking down the filter bags, empty the dust box.



AM.62

Figure 11-15.–Proper operation of gun.

Four-Hour Intervals.–Open the drain cock at the bottom of the air filter and drain moisture every 4 hours, or whenever visible. Additional maintenance and lubrication requirements are defined in NavAir 17-5BM-1.

CAUTION: Care must be taken to prevent damage to the plastic air filter bowl. Mechanical damage or contact with common solvents will cause it to shatter when pressurized. If necessary to clean the bowl, use only water or a mild detergent solution.

LIMITATIONS.–The dry honing machine described in the aforementioned sections can cause damage to aircraft components and systems if improperly used. Small quantities of abrasive may be expected to escape from the blast nozzle during normal use; therefore, the equipment must not be used in areas or under conditions where the abrasive may contaminate systems or components.

1. Do not use on engines, gear boxes, or other oil lubricating systems.
2. Do not use on fuel, hydraulic, or oxygen system components.

3. Mask vents of the above listed systems when blasting near them to prevent possible contamination.

4. Use only on exterior surfaces or parts which have been removed from the airframe to prevent possible contamination of interior areas.

5. Do not use on airframes skins or structural parts which are exposed to over 500° F in service.

6. Do not blast Metallite or honeycomb panels.

NOTE: Corrosion PREVENTIVE maintenance is documented on a Support Action Form, while corrosion maintenance that is considered as TREATMENT must be documented on the Maintenance Action Form so that a record of extensive corrosion rework will exist and be available for any Aircraft Logbook entries that may be required.

CORROSION DAMAGE LIMITS

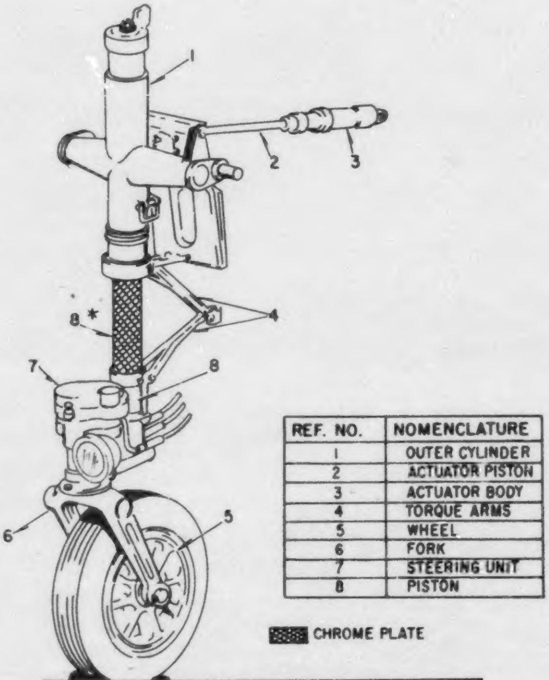
The term "corrosion damage limits" refers to the amount of metal which may be removed from a corroded part and still maintain the required safe margin of strength and function. When removing corrosion, maintenance personnel must be very careful not to remove more of the metal than is absolutely necessary to insure complete removal of corrosion. Figure 11-16 illustrates the maximum corrosion depths allowed on the various components of the nose landing gear on one late model aircraft.

Damage which exceeds those limits specified in the applicable Structural Repair Manual or the Corrosion Control section of the applicable Maintenance Instructions Manual necessitates replacement of the affected part if actual structural repair of the damage is not possible or feasible.

CHEMICAL SURFACE TREATMENT

Chemical conversion coatings will increase corrosion resistance and improve paint adhesion. After cleaning and removal of any surface oxides, aluminum and magnesium should be treated with MIL-C-5541 chemical treatment. These coatings are often damaged during aircraft maintenance or are contaminated by grease, oil, or other foreign matter. Therefore, the treated surface should be painted soon after treating if best results are to be expected.

Soluble salt residues remaining on the surface after treatment will accelerate corrosion and can cause blistering of paint finishes. Thus, complete rinsing with fresh water following the chemical treatment is very important. Flush the chemical with free-flowing water only. DO NOT wipe the area with a damp cloth or brush as this will deteriorate or remove the chemical conversion



REF. NO.	NOMENCLATURE
1	OUTER CYLINDER
2	ACTUATOR PISTON
3	ACTUATOR BODY
4	TORQUE ARMS
5	WHEEL
6	FORK
7	STEERING UNIT
8	PISTON

▨ CHROME PLATE

MAXIMUM CORROSION DEPTH		
REF. NO.	MATERIAL	MAX DEPTH
1	ALUMINUM	0.015
2	CHR PLATED STEEL	0.003
3	ALUMINUM	0.030
4	ALUMINUM	0.030
5	MAGNESIUM	0.030
6	HEAT RESISTANT STEEL	0.010
7	HEAT RESISTANT STEEL	0.010
8	HEAT RESISTANT STEEL	0.010
8*	CHROME PLATED HEAT RESISTANT STEEL	0.004

AM.63

Figure 11-16.—A-5 nose gear-maximum corrosion depths.

coating, which is sensitive to abrasion prior to fully drying.

CAUTION: Personnel should wear goggles, aprons, and rubber gloves when using solutions of MIL-C-5541.

Chemical Conversion of Aluminum Alloys

The procedure to be used for the chemical conversion of aluminum alloys is as follows:

1. Insure that the surface is clean.
2. Brush MIL-C-5541 solution on areas to be treated. Repeat application of fresh solution until a uniform irridescent yellow to brown color is produced, then discontinue brushing and allow the solution to remain on the metal for about 1 minute.
3. Rinse the complete area with fresh water.
4. Allow to air dry (usually not more than 1 hour) before priming. A powdery coating indicates poor rinsing or failure to keep the surface wet during the treatment. If this occurs, the treatment should be repeated.

NOTE: Chemical treatments conforming to Specification MIL-C-5541 are not all the same composition and therefore should be prepared for use according to the particular manufacturer's instructions.

Chemical Conversion of Magnesium Alloys

Procedure for the chemical conversion of magnesium alloys is as follows:

1. Insure that the surface is clean.
2. While the surface is still wet, brush on MIL-C-5541 chemical treatment solution. Continue application of fresh solution on the metal until a uniform light brown color is obtained.

NOTE: The solution for magnesium is the same as used for aluminum and is made up according to the manufacturer's aluminum treatment instructions. The solution will react much more rapidly with magnesium than with aluminum.

3. Rinse thoroughly as with the aluminum treatment and allow to air dry prior to applying protective paint finishes.

Some magnesium parts in later model aircraft have been originally protected by a proprietary (held under patent) electrolytic process. The "HAE" process is identified by the brown to mottled gray appearance of the unpainted surface. "DOW 17" coatings will appear as a green to grayish green color. These coatings are generally thicker than those applied by immersion or brush method such as MIL-C-5541. The electrolytic finish cannot be restored in the field. Therefore, when failure of the coating occurs, any corrosion should be removed and the bare magnesium should be touched up with MIL-C-5541 chemical treatment solution. Care should be taken to minimize removal of the electrolytic coatings as they afford greater protection than the replacement coatings.

CORROSION CONTROL KIT

A corrosion control kit is available for operating activities and is especially useful for small detachments. The kit is primarily designed for use in treating small areas of corrosion and contains all the necessary materials and equipment. A compartmented case provides orderly storage of materials. Most materials are identical to materials discussed in this chapter.

A maskant material is provided to use in paint stripping operations. The maskant is squeezed around the area to be stripped and forms a dam to protect areas where paint remover is not desired. The maskant must be high enough to contain the paint remover. After the paint is lifted or softened, the loosened paint, paint remover, and maskant material are removed by using the micarta scraper, which is provided in the kit, to work the material toward the center of the encircled area. The residue is then scraped into a disposable plastic bag. A washing bottle is provided for rinsing the area following stripping and chemical treatment of the corroded area.

The epoxy polyamide primer packages are supplied in plastic squeezable bags. At least 1 hour prior to use, the two components are mixed by pressing the inner bag of component two, so that it breaks, and then kneading the outer bag until the two components are thoroughly mixed. When ready to use, the top of the bag is opened and the primer brushed on. Topcoat is available in aerosol spray cans.

All other materials are common to corrosion maintenance personnel. Complete instructions or appropriate reference to the Cleaning and Corrosion Control Manual is provided in each kit with the arrangement of materials supplied in the kit printed on the back of the instruction sheet. Materials in the kit may be replenished from standard stock as necessary to maintain the kit.

AIRCRAFT AND COMPONENT PAINTING AND PAINT TOUCHUP

The amount of paint touchup accomplished at the Organizational and Intermediate level will vary widely with the activity involved, the availability of facilities, and the area of operations.

The primary objective of any paint finish is the protection of exposed surfaces against deterioration. There are secondary reasons for particular paint schemes; the reduction of glare by nonspecular coatings, the use of white or light colored high-gloss finishes to reduce heat absorption, camouflage or high visibility requirements, or special identification markings. There is seldom justification for repainting for appearance sake only. A faded or stained, but well-bonded, paint finish is better than a fresh touchup treatment improperly applied over dirt, corrosion products, or other contaminants.

Complete refinishing, particularly under field conditions, should be restricted to those areas where existing paint finishes have deteriorated, through age and exposure, until they fail to perform their protective function. Renewal of special finishes and markings should also be restricted to those situations where the purpose of the special finish is not being served. However, maintenance and repair of paint finishes at the Organizational and Intermediate level is extremely important, from the evaluation of initial paint finishes at the time of aircraft receipt, through the constant surveillance and maintenance of finishes during a service tour, to the final recommendations for refinishing requirements when the aircraft is scheduled for Progressive Aircraft Rework at the Depot level of maintenance.

SURFACE PREPARATION

Much of the effectiveness of any paint finish and its adherence depends on the careful preparation of the damaged surface prior to touchup. The procedures to be used in paint and corrosion removal have been described previously. The touchup paint should overlap onto the existing good paint finish. The touchup materials will not adhere properly to glossy finishes. Also, any edges of the existing film will show through the overlap unless they are smoothed out.

To break the gloss of existing finishes and to feather (smooth out) the edges for overlap, scuff sand, using 300 to 400 aluminum oxide paper. Following sanding, a water rinse is used to remove the abrasive residues.

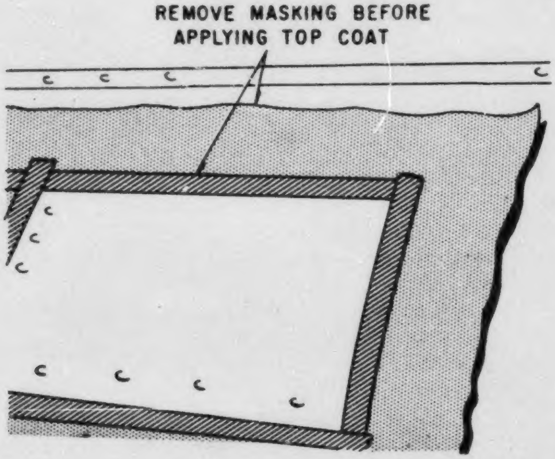
Next, all sanded areas and exposed bare metal surfaces are wiped down with 1-BUTANOL (normal butyl alcohol).

Remove any loosened seam sealants in the area to be touched up and replace as necessary. (See Sealants and Sealing Practices in this chapter.) Also, resecure any loose rubber seals, using the type adhesive specified in the applicable Maintenance Instructions Manual.

The area to be painted is then outlined with tape and masking paper as shown in figure 11-17. This protects the adjoining surfaces from over-spray and unwanted paint buildup.

TOUCHUP PROCEDURES

In the past, it was necessary to identify the specific surface finish (paint system) applied to an aircraft at the time of manufacture or rework. Each surface finish (nitrocellulose lacquer, acrylic lacquer, and epoxy) required a specific touchup procedure that was compatible with the present finish. Failure to properly identify the present surface finish and apply the specific touchup procedures, usually resulted in wasted manhours and material.



AM.64
Figure 11-17.—Masking prior to paint touchup.

To preclude this and more effectively control corrosion, a standardized paint system for Organizational and Intermediate level painting and paint touchup has been promulgated by the Naval Air Systems Command. This system consists of an improved epoxy primer, Specification MIL-P-23377B and an acrylic topcoat, Specification MIL-L-81352, and is compatible with all of the various systems presently used in naval aircraft.

Epoxy-Polyamide Primer (MIL-P-23377B)

The epoxy-polyamide primer is supplied as a two-part kit, each part of which must be stirred or shaken thoroughly before mixing. One part contains the pigment, ground in an epoxy vehicle, while the other part is composed of a clear polyamide solution which functions as a hardner for the epoxy solution. This primer is supplied by various manufacturers. Mix only as much primer as needed, as the storage life of the primer is limited after mixing. CAUTION: Do not substitute part 1 or part 2 from another manufacturer. Established mixing ratios supplied by the manufacturer must be followed,otherwise the primer will exhibit unsatisfactory properties, such as poor adhesion, poor chemical resistance, or inadequately dried film.

For mixing, pour the specified amount of part 1 into an empty container, then slowly pour part 2 into the container, stirring constantly.

CAUTION: Always add part 2 to part 1.

To thin the primer for spraying, add 1 1/2 parts thinner, Specification MIL-T-19588, to 2 parts primer. The thinned primer should be stirred thoroughly, strained, and allowed to stand 1 hour prior to use. If necessary the thinning ratio may be varied slightly to obtain the proper spraying viscosity. The 1-hour standing time is necessary to permit the components to enter into chemical reaction, shorten drying time, reduce cratering, preclude part 2 from "sweating out" or migrating, and to allow any bubbles (formed while stirring) to escape.

To apply the primer, insure that the surface to be primed has been cleaned, chemically treated, and prepared for spraying as previously described in this section. Apply a wet coat of epoxy primer to 1 mil thickness and allow to dry from 1 to 2 hours. One hour is sufficient when temperature and humidity range is ideal.

Acrylic Lacquer Topcoat (MIL-L-81352)

This acrylic lacquer is used as a general purpose external coating for metal surfaces. It is applied directly over the epoxy-polyamide primer. It is available in all colors for touchup and insignia marking directly over all paint systems presently employed on naval aircraft.

To thin the acrylic lacquer topcoat for spraying, mix 1 volume of lacquer with approximately 1 1/2 volumes of thinner. The thinner used with this lacquer is composed of equal parts by volume of toluene and xylene. The exact thinning ratio must be determined by the user and adjusted to the prevailing temperature, relative humidity, and type of spraying equipment being used. Increasing the xylene portion promotes better flowout and reduces dry spray but also prolongs drying time.

After thinning the acrylic lacquer to spraying viscosity, it should be applied in two spray coats with a 30-minute air-dry interval between coats.

Table 11-1.—Acrylic topcoat application, possible defects and methods for correction.

Problem	Cause/Correction
Webbing.	1. Insufficient thinning.
Dry spray.	1. Insufficient thinning. 2. Increase the proportion of the slower evaporating xylene in the xylene-toluene mixture.
Orangepeel or poor flowout.	1. Insufficient thinning 2. Increase the proportion of the slower evaporating xylene in the xylene-toluene mixture. 3. Poor spray technique.
Slow drying.	1. Increase the proportion of faster evaporating toluene in the xylene-toluene blend.
Bleeding through or lifting of primer.	1. Allow epoxy primer to dry longer. 2. First coat of lacquer topcoat was applied too wet (first coat can also be misted on). 3. Too rich solvents used to reduce lacquer topcoat; decrease proportion of thinner.

The total dry film thickness of the acrylic topcoat should be 0.8 to 1.2 mils.

To apply insignia and/or squadron markings over the acrylic topcoat, begin masking after the coating has dried tack-free. Apply the tape with a minimum of pressure to avoid marking and possible damage to the topcoat. The insignia and/or markings are then applied directly over the topcoat. NOTE: Do not use epoxy primer when repainting or doing touchup work over Specification MIL-L-81352 acrylic lacquer topcoat.

When painting insignia and/or squadron markings over all other paint systems, use the epoxy primer and then overcoat with the acrylic lacquer.

CAUTION: The materials used for painting and paint touchup are toxic and flammable. Precautions must be taken to assure respiratory (face mask) and eye protection for personnel engaged in mixing and spraying paint and/or primers. Gloves and aprons should also be used to prevent skin contact. The mixing and application of paints and primers should be done in well-ventilated spaces only.

Paint touchup in the field is a difficult task. Table 11-1 lists some of the problems encountered during paint application, the most probable cause, and methods for correction.

Polyurethane Finish Systems

In its present search for better quality protective finishes, the Naval Air Systems Command has authorized that certain aircraft receive exterior polyurethane finishes.

The polyurethane finish is available in kits consisting of a two-component material—resin and catalyst. The touchup kits are prethinned and ready for use when mixed in accordance with the instructions in the kit.

One-gallon kits are available for production type spraying. They consist of 3 1/2 quarts of resin and 1 pint of catalyst, providing a 7 to 1 mixing ratio. Thinning with a suitable reducer, as specified by the manufacturer, is required to obtain a proper spraying viscosity.

Polyurethane finishes are applied over epoxy polyamide primer which has been allowed to dry for 1 hour. The primer is then scuffed with 400-grit paper to remove any dry, rough areas which could adversely affect the leveling of the polyurethane film. Apply one even, light topcoat of polyurethane, allow to dry for 15 to 45 minutes, then apply a final full topcoat. Insignia white polyurethane has a slight translucent characteristic and may require the application of one additional coat to obtain an adequate shadow-free finish. The total topcoat dry film thickness should not exceed 1.5 mils. Glossy colors will normally dry in approximately 6 to 8 hours. Camouflage colors will dry in approximately 4 to 5 hours.

Enamel Finishes

Most enamel finishes used on aircraft surfaces are baked finishes that cannot be touched up with the same materials in the field.

Minor damage to conventional enamel finishes ordinarily used on engine housings is repaired by touching up with epoxy topcoat material or air-drying enamel.

Elastomeric Rain Erosion Resistant Coating (MIL-C-7439)

Elastomeric coatings are used as a coating system to protect exterior laminated plastic parts of high-speed aircraft, missiles, and helicopter rotary blades from rain erosion in flight. They offer good resistance to weather and aromatic fuels in addition to rain erosion. Excellent adhesion is obtained after a 7-day drying period.

Repairs to these coatings in the field are impracticable due to this long curing time. Kits are available for repair of coatings where limited touchup is required. These kits contain a primer, neoprene topcoat, and antistatic coating. If the radome or leading edge coatings are in bad condition, they should be stripped completely and recoated with epoxy primer and acrylic topcoat as a temporary measure. If schedules and conditions permit adequate curing of elastomeric coatings, these original coatings may be replaced.

The repair kits are normally bought open purchase to insure that fresh materials are available. They should be stored in a cool place or refrigerated, as heat accelerates aging. Stripping of fiberglass surfaces should be in accordance with current maintenance instructions. Elastomeric coatings are toxic and flammable and must be used with care.

AIRCRAFT PAINTING EQUIPMENT AND TECHNIQUES

The AMS is called upon many times to use his skill and knowledge in the painting of aircraft. This type of work is normally performed during preventive maintenance inspections or when aircraft painted surfaces warrant touchup repairs.

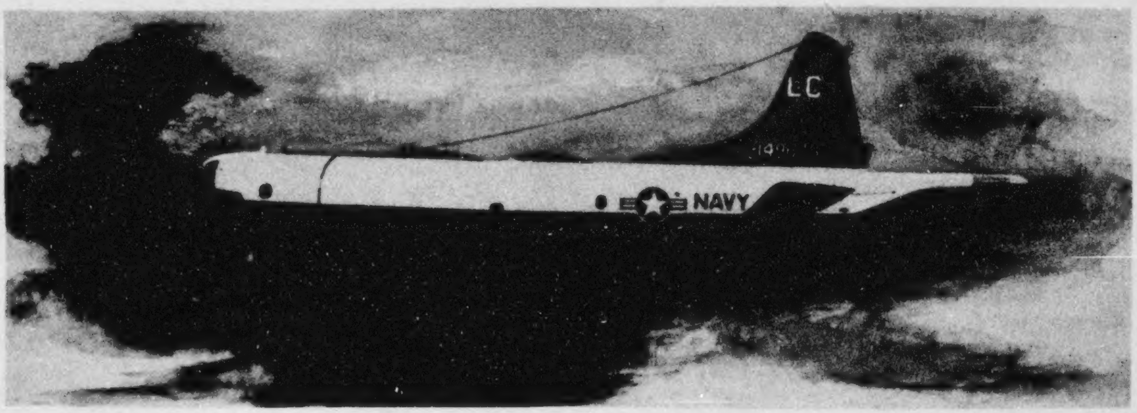
New aircraft normally assigned to an activity are usually required to have the following markings painted on the aircraft: Squadron designation (example, VP-8); modex number (example, 5); unit identifying letter or letters (example, LC); and at times a large bureau aircraft serial number (example, 149673). (See fig. 11-18.)

Since types of paints were discussed earlier in the chapter, only the equipment and techniques in painting aircraft are covered in this section.

PAINTING EQUIPMENT

Spray Guns

The spray gun atomizes the material to be sprayed and the operator directs and controls the spray pattern through manipulation and minor adjustments of the spray gun. Spray guns are usually classed as either suction-feed or pressure-feed type. The types can be divided by two methods—by the type of container used to hold the paint material, and by the method in which the paint is drawn through the air cap assembly.



AM.418

Figure 11-18.—Aircraft markings.

SUCTION-FEED TYPE.—The suction-feed spray gun is designed for small jobs. The container for the paint is connected to the spray gun by a quick-disconnect fitting, as illustrated in figure 11-19. The capacity of this container is approximately 1 quart. The fluid tip of this type spray gun protrudes through the air cap as illustrated in figure 11-20. The air pressure rushing by the fluid tip causes a low-pressure area in front of the tip. This causes paint to be drawn up through the fluid tip where it is atomized outside the cap by the air pressure.

PRESSURE-FEED TYPE.—The pressure-feed type spray gun is designed for use on large jobs where a large amount of spray materials is to be used. With this type, the spray material is supplied to the gun through a hose from a pressurized tank. This spray gun is designed to operate on a high volume and low air pressure. This type of spray equipment eliminates evaporation of the volatile substances of the mixture before striking the surface since the paint and air are mixed internally; in other words, a wetter coating is applied.

Spray Gun Maintenance

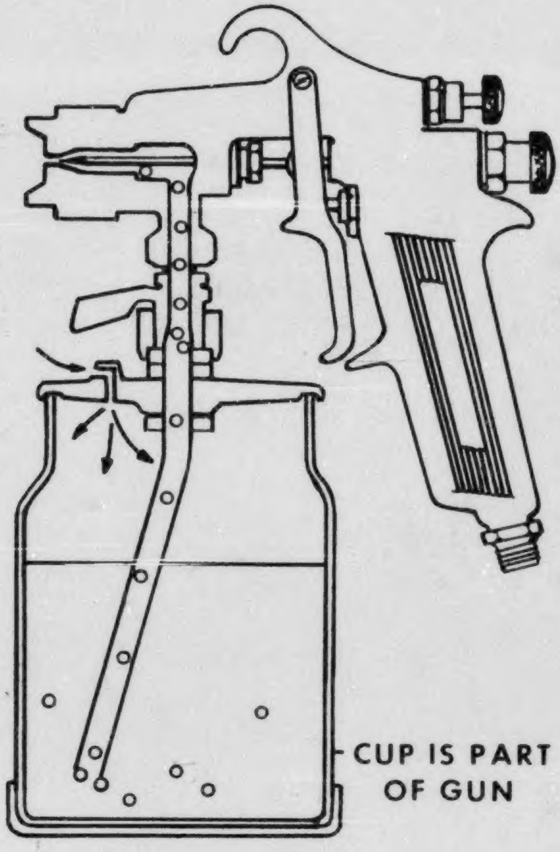
FLUID LEAKAGE.—Fluid leakage at the front of the gun is an indication that the fluid needle is not seating properly. This may be caused by a fleck of dried material in the nozzle, or the fluid needle packing may be too tight. It may also be caused by a bent fluid needle, a broken fluid needle spring, or the wrong size fluid needle for the fluid tip.

AIR LEAKAGE.—Air leakage is a result of improper setting of the air valve. This may be caused by a bent valve stem, a broken spring, or a damaged valve or valve seat.

JERKY OR FLUTTERING SPRAY.—Jerky or fluttering spray is caused by obstructed fluid passage, loose tip or damaged seat, and air in the fluid line. The air can be inducted from several points on the equipment, loose packing nut or dried out packing, loose or damaged coupling nut, loose or damaged fluid tube, lack of sufficient material, and cup tipped too far. (See fig. 11-21.)

FAULTY SPRAY PATTERNS.—Faulty spray patterns, their causes, and how to correct them are shown in figure 11-22.

CLEANING SPRAY GUNS.—Spray guns should be cleaned immediately after each use. To clean the suction type gun, empty the container and pour in a small quantity of thinner or suitable solvent. Draw the thinner or suitable solvent through the gun by inserting the tube into the container of cleaning fluid. Move the trigger constantly to thoroughly flush passageways and the tip of the fluid needle. Remove the

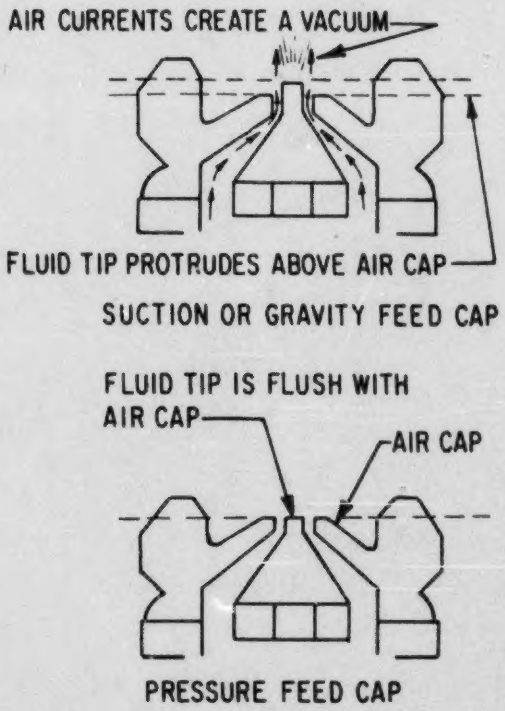


AM.419

Figure 11-19.–Suction-feed type spray gun.

air cap and soak it in solvent. If this does not clear the small holes in the air cap, remove the paint material, using a toothpick or broomstraw. Do not use wire or other metal objects which may cause permanent damage to the air cap.

To clean a pressure-feed gun, proceed as follows: Back off the fluid needle adjusting screw. Release the pressure from the pressure tank by means of the relief or safety valve. Hold a cloth over the air cap and operate the gun trigger. This forces the spray material back into the pressure tank. (See fig. 11-23.) Remove the fluid hose from the gun and pressure tank. Attach hose cleaner to hose and run thinner or suitable solvent through to clean the hose. Place the air cap


AIR CURRENTS CREATE A VACUUM
FLUID TIP PROTRUDES ABOVE AIR CAP
SUCTION OR GRAVITY FEED CAP
FLUID TIP IS FLUSH WITH AIR CAP
AIR CAP
PRESSURE FEED CAP

AM.420

Figure 11-20.–Suction and pressure fluid tips and air caps.

in the cleaning fluid as stated above for the suction type gun.

NOTE: Do not immerse an entire spray gun in cleaning materials such as cleaning solvents and thinners. These materials dissolve the oil from leather packings and cause the gun to have an unsteady spray.

LUBRICATION OF SPRAY GUNS.–The following parts of a spray gun require frequent lubrication: Fluid needle packing, air valve stem, and trigger bearing screw. Remove the fluid needle packing before using the gun and soften it with oil. The fluid needle spring should be coated with a specified grease. (See fig. 11-24.)

Air Compressors

In order to use spray guns, a source of compressed air is necessary. Figure 11-25 illustrates two types of air compressors–a portable unit

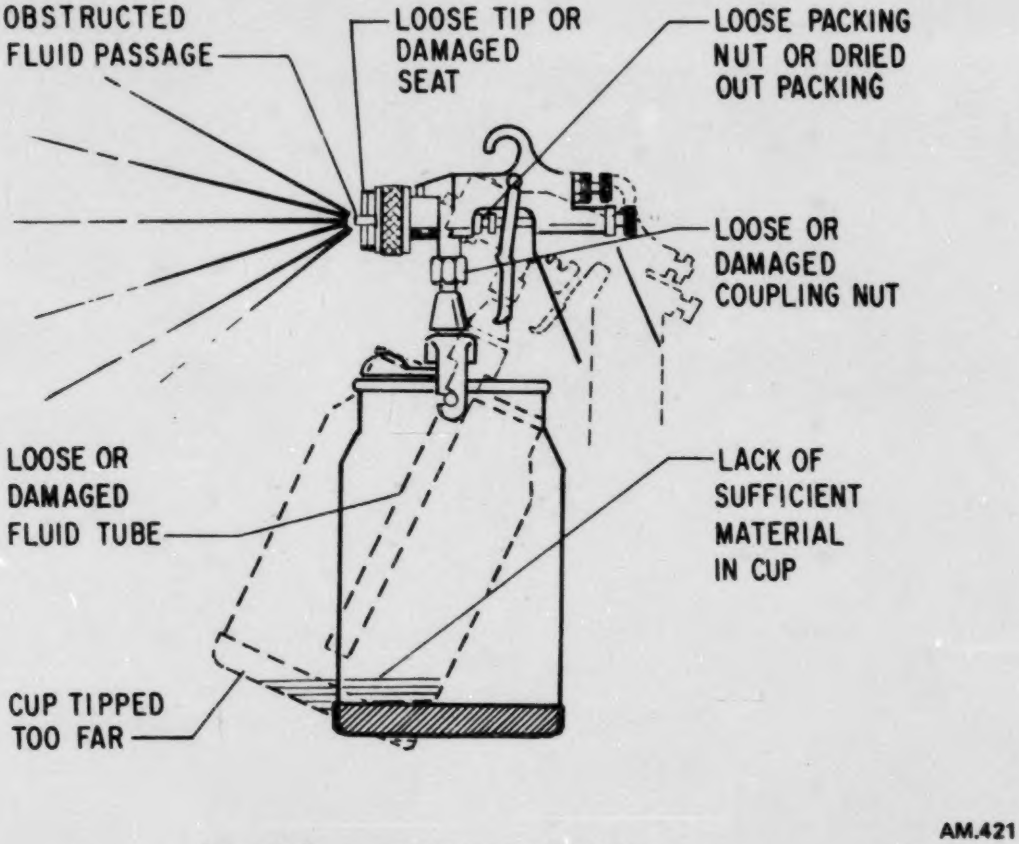

OBSTRUCTED FLUID PASSAGE
LOOSE TIP OR DAMAGED SEAT
LOOSE PACKING NUT OR DRIED OUT PACKING
LOOSE OR DAMAGED COUPLING NUT
LOOSE OR DAMAGED FLUID TUBE
LACK OF SUFFICIENT MATERIAL IN CUP
CUP TIPPED TOO FAR
AM.421

Figure 11-21.—Causes of jerky or fluttering spray.

and a stationary unit. Both types are in common use.

The portable unit consists of an electric motor (or gasoline engine) for driving the unit, a compressor, storage tank, automatic unloader mechanism, and wheels and handle for moving the unit.

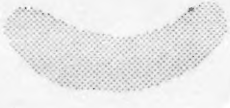
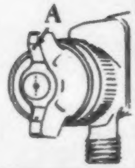
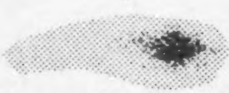
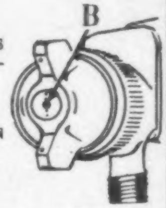
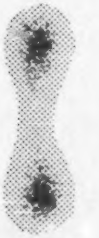
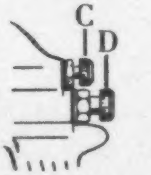
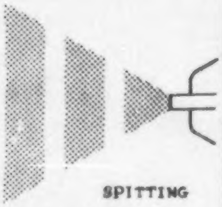
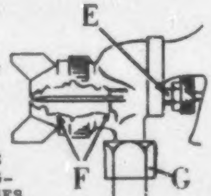
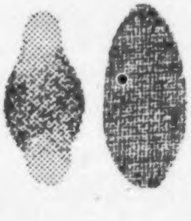
The stationary unit consists of an electric motor, compressor, storage tank, centrifugal pressure release, pressure switch, and mounting feet.

Some of the more common compressor troubles are illustrated in figure 11-26.

Air Regulators

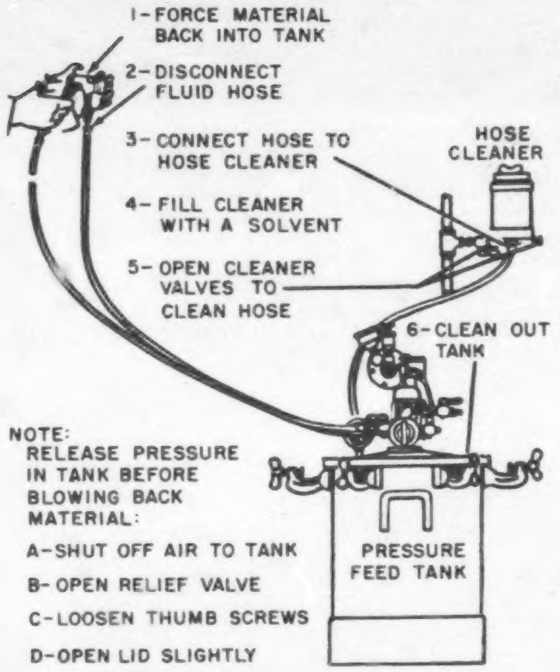
The air regulator (or transformer) is used to regulate the amount of air pressure to the spray gun and to clean the air. The air delivered to the regulator always contains some oil from the compressor and some water caused by condensation, and many particles of dirt and dust.

Air regulators are equipped with a pressure valve and pressure regulating screw. This makes it possible to regulate exactly the pressure delivered to the spray gun and prevents any pressure fluctuations. The air must pass through a sack or cleaner before it leaves the regulator. This cleaner is contained in the long cylindrical part of the regulator.

PATTERN	CAUSE	CORRECTION
	DRIED MATERIAL IN SIDE-PORT "A" RESTRICTS PASSAGE OF AIR THROUGH IT. RESULT: FULL PRESSURE OF AIR FROM CLEAN SIDE-PORT FORCES FAN PATTERN IN DIRECTION OF CLOGGED SIDE. 	DISSOLVE MATERIAL IN SIDE-PORT WITH THINNER. DO NOT POKE IN ANY OF THE OPENINGS WITH METAL INSTRUMENTS.
	DRIED MATERIAL AROUND THE OUTSIDE OF THE FLUID NOZZLE TIP AT POSITION "B" RESTRICTS THE PASSAGE OF ATOMIZING AIR AT ONE POINT THROUGH THE CENTER OPENING OF AIR NOZZLE AND RESULTS IN PATTERN SHOWN. THIS PATTERN CAN ALSO BE CAUSED BY LOOSE AIR NOZZLE. 	IF DRIED MATERIAL IS CAUSING THE TROUBLE, REMOVE AIR NOZZLE AND WIPE OFF FLUID TIP, USING RAG WET WITH THINNER. TIGHTEN AIR NOZZLE.
	A SPLIT SPRAY OR ONE THAT IS HEAVY ON EACH END OF A FAN PATTERN AND WEAK IN THE MIDDLE IS USUALLY CAUSED BY (1) TOO HIGH AN ATOMIZING AIR PRESSURE, OR (2) BY ATTEMPTING TO GET TOO WIDE A SPRAY WITH THIN MATERIAL.	REDUCING AIR PRESSURE WILL CORRECT CAUSE (1). TO CORRECT CAUSE (2), OPEN MATERIAL CONTROL "D" TO FULL POSITION BY TURNING TO LEFT. AT THE SAME TIME TURN SPRAY WIDTH ADJUSTMENT "C" TO RIGHT. THIS WILL REDUCE WIDTH OF SPRAY BUT WILL CORRECT SPLIT SPRAY PATTERN 
	(1) DRIED OUT PACKING AROUND MATERIAL NEEDLE VALVE PERMITS AIR TO GET INTO FLUID PASSAGEWAY. THIS RESULTS IN SPITTING. (2) DIRT BETWEEN FLUID NOZZLE SEAT AND BODY OF A LOOSELY INSTALLED FLUID NOZZLE WILL MAKE A GUN SPIT. (3) A LOOSE OR DEFECTIVE SWIVEL NUT ON SIPHON CUP OR MATERIAL HOSE CAN CAUSE SPITTING.	TO CORRECT CAUSE (1) BACK UP KNURLED NUT (E), PLACE TWO DROPS OF MACHINE OIL ON PACKING, REPLACE NUT AND TIGHTEN WITH FINGERS ONLY. IN AGGRAVATED CASES, REPLACE PACKING.  TO CORRECT CAUSE (2), REMOVE FLUID NOZZLE (F), CLEAN BACK OF NOZZLE AND NOZZLE SEAT IN GUN BODY USING RAG WET WITH THINNER, REPLACE NOZZLE AND DRAW UP TIGHTLY AGAINST BODY. TO CORRECT CAUSE (3) TIGHTEN OR REPLACE SWIVEL NUT (G).
	A FAN SPRAY PATTERN THAT IS HEAVY IN THE MIDDLE, OR A PATTERN THAT HAS AN UNATOMIZED "SALT-AND-PEPPER" EFFECT INDICATES THAT THE ATOMIZING AIR PRESSURE IS NOT SUFFICIENTLY HIGH.	INCREASE PRESSURE FROM YOUR AIR SUPPLY. CORRECT AIR PRESSURES ARE DISCUSSED ELSEWHERE IN THIS CHAPTER.

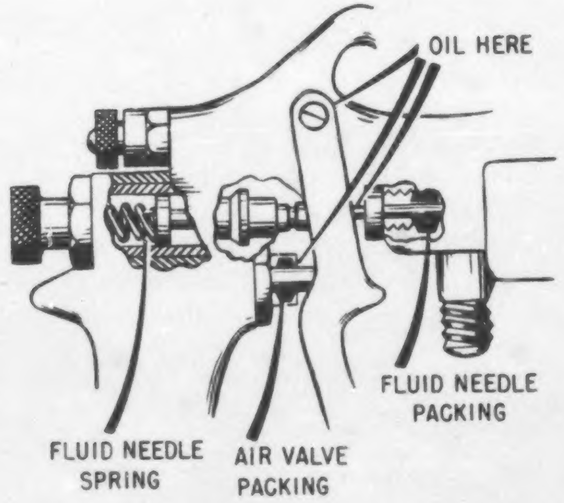
AM.422

Figure 11-22.—Faulty spray patterns and how to correct them.


1-FORCE MATERIAL BACK INTO TANK
2-DISCONNECT FLUID HOSE
3-CONNECT HOSE TO HOSE CLEANER
HOSE CLEANER
4-FILL CLEANER WITH A SOLVENT
5-OPEN CLEANER VALVES TO CLEAN HOSE
6-CLEAN OUT TANK
NOTE:
RELEASE PRESSURE IN TANK BEFORE BLOWING BACK MATERIAL:
A-SHUT OFF AIR TO TANK
B-OPEN RELIEF VALVE
C-LOOSEN THUMB SCREWS
D-OPEN LID SLIGHTLY
PRESSURE FEED TANK

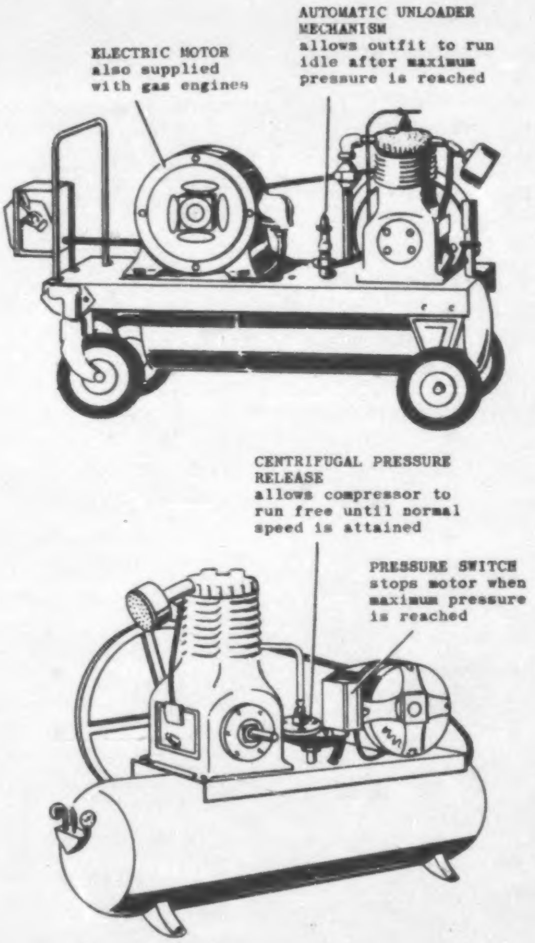
AM.423

Figure 11-23.—Cleaning pressure-feed spray gun.



AM.424

Figure 11-24.—Spray gun lubrication points.


AUTOMATIC UNLOADER MECHANISM
allows outfit to run idle after maximum pressure is reached
ELECTRIC MOTOR
also supplied with gas engines
CENTRIFUGAL PRESSURE RELEASE
allows compressor to run free until normal speed is attained
PRESSURE SWITCH
stops motor when maximum pressure is reached

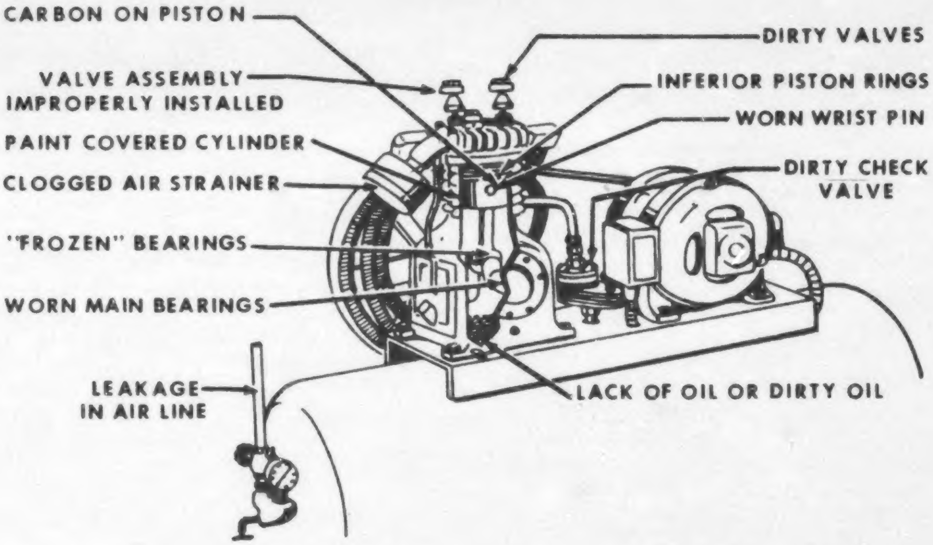
AM.425

Figure 11-25.—Air compressors.

Air regulators are equipped with two gages. One gage shows the pressure on the main line while the other shows the pressure to the spray gun. A complete compressor and air regulator installation is shown in figure 11-27.

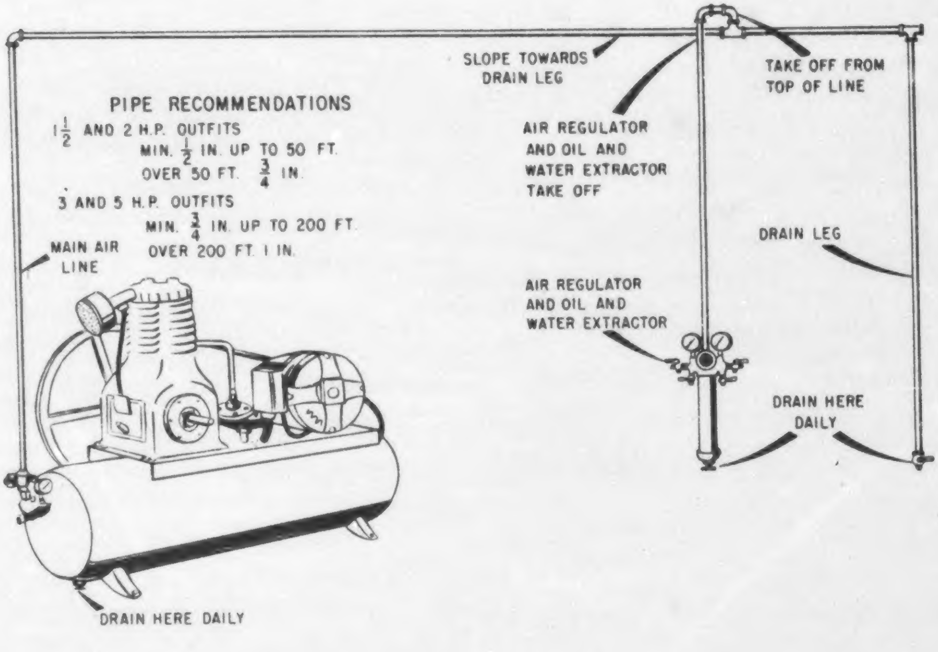
Spray Gun Technique

Proper spray gun technique is acquired and developed through knowledge of the equipment and experience of the operator. The spray gun



AM.426

Figure 11-26.–Possible compressor troubles.


SLOPE TOWARDS DRAIN LEG
TAKE OFF FROM TOP OF LINE
PIPE RECOMMENDATIONS
$1\frac{1}{2}$ AND 2 H.P. OUTFITS
MIN. $\frac{1}{2}$ IN. UP TO 50 FT.
OVER 50 FT. $\frac{3}{4}$ IN.
3 AND 5 H.P. OUTFITS
MIN. $\frac{3}{4}$ IN. UP TO 200 FT.
OVER 200 FT. 1 IN.
AIR REGULATOR AND OIL AND WATER EXTRACTOR TAKE OFF
MAIN AIR LINE
DRAIN LEG
AIR REGULATOR AND OIL AND WATER EXTRACTOR
DRAIN HERE DAILY
DRAIN HERE DAILY

AM.427

Figure 11-27.–Compressor and air regulator installation.

should be held so that the spray is perpendicular to the area to which the finish is being applied. Great care should also be taken to insure that the prescribed distance from the gun to the work is maintained.

The gun should be held from 8 to 10 inches from the work for spraying lacquer and 6 to 8 inches for spraying enamels, depending on the width of the spray pattern. Generally, with a narrow pattern, the gun is held the farther distances from the work (10 inches for lacquer and 8 inches for enamels).

In general, a distance of less than 6 inches is undesirable, since the paint will not atomize properly, and "orangepeel" will result. A distance of more than 10 inches is equally undesirable, since dried particles of paint will strike the surface and cause "dusting" of the finish.

Examples of correct and incorrect spray gun techniques are shown in figure 11-28.

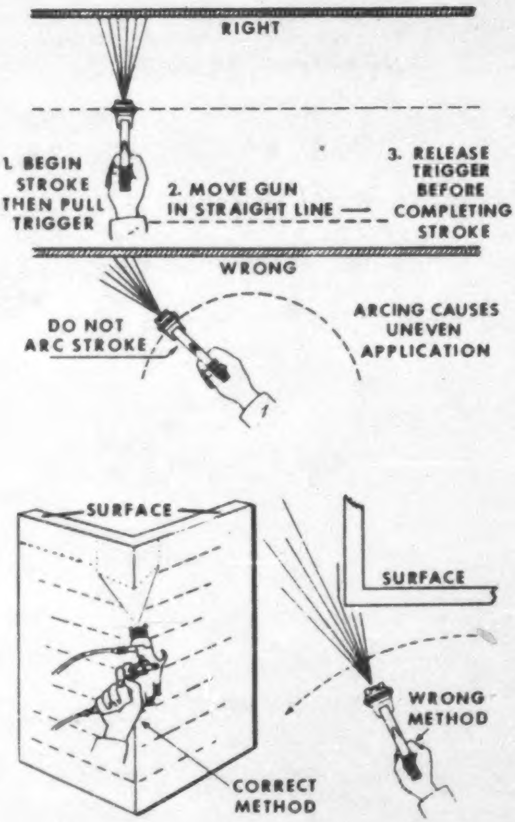
The distance the spray gun is held from the work is very important; however, there are other factors which must be considered and mastered. The manner in which the gun is held and operated is illustrated in figure 11-28. Move the arm and body with the gun to keep the spray perpendicular to the surface. Avoid pivoting or any circular movements of the wrist or forearm which will bring the gun closer to the surface when directly in front of the body.

It is important to "trigger" the gun in order to avoid an uneven coat building up at the beginning and end of a stroke. Triggering is the technique of starting the gun moving toward the area to be sprayed before the trigger is pulled, and continuing the motion of the gun after the trigger has been released.

Care must be taken to avoid too much overlapping on each pass of the gun or an uneven coat will result. The rate of stroke should be such as to produce a full, wet, even coat.

Once the job is started it must be carried through to completion without stopping.

SPRAY GUN ADJUSTMENTS.–Figure 11-29 illustrates the principal parts of a typical spray gun, including the various adjustment points. The spreader adjustment dial is used in adjusting the width of the spray pattern. By turning the dial to the right, a round pattern is obtained; turning to the left gives a fanshaped pattern.

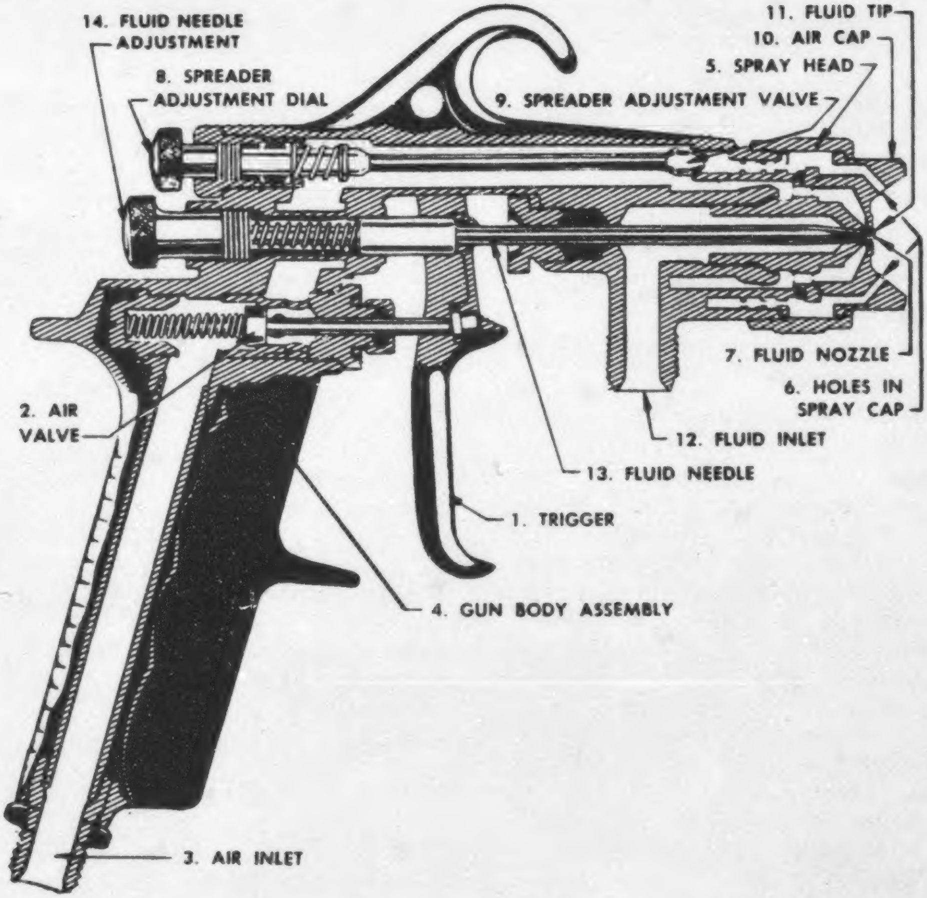

RIGHT
1. BEGIN STROKE THEN PULL TRIGGER
2. MOVE GUN IN STRAIGHT LINE
3. RELEASE TRIGGER BEFORE COMPLETING STROKE
WRONG
DO NOT ARC STROKE
ARCING CAUSES UNEVEN APPLICATION
SURFACE
SURFACE
CORRECT METHOD
WRONG METHOD

AM.428

Figure 11-28.–Correct and incorrect methods of spraying.

As the width of the spray is increased, more material must be allowed to pass through the gun to get the same coverage on the increased area. To apply more material to the area, the operator should turn the fluid needle adjustment (fig. 11-29) to the left. If too much material is applied to the surface, turn the fluid needle adjustment to the right.

In normal operation of the spray gun, the wings on the air cap are adjusted to the horizontal position, as illustrated in figure 11-30. This provides a vertical fan-shaped pattern, given maximum coverage as the gun is



AM.429

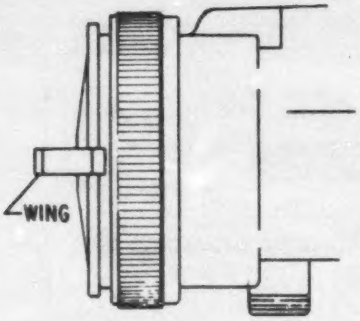
Figure 11-29.–Sectional view of typical spray gun.

moved back and forth parallel to the surface being painted.

SPRAYING PRESSURES.–Normally, the AMS will be concerned with spray painting lacquer, enamel, and epoxy materials. The correct air and fluid pressures used with these materials vary and are important in all spray painting applications. There are several pitfalls of incorrect pressures, some of which are listed below:

1. Too high an air pressure alone causes dusting of finish and rippling.
2. Too low an air pressure, coupled with too high fluid pressure, causes orangepeel.
3. Too high fluid pressure alone causes orangepeel and sags.
4. Too low fluid pressure alone causes dusting.

When using 20-foot air and fluid pressure hoses, maintain a pressure of approximately 45



AM.430

Figure 11-30.—Spray gun nozzle.

psi at the spray gun for lacquer and 50 psi for enamel and epoxy. This pressure is measured at the gun. Sufficient pressure must be maintained at the main line pressure regulator to obtain the above pressures and to compensate for the pressure drops encountered if additional lengths of hose are employed. The pressure at the gun should be rechecked if the main line pressure is changed for any reason. Fluid tank pressure for lacquer should be 8 to 12 psi. A 3-pound increase above these figures should be used in the case of enamel and epoxy. A proportionate increase in pressure for lacquer and epoxy should be allowed for additional lengths of hose up to 50 feet maximun. One-pound fluid pressure may be added for each foot of height of the gun from the fluid tank level. Make frequent checks with a test gage of air pressure at the gun.

SEALANTS AND SEALING PRACTICES

Sealants are used to prevent the movement of liquid or gas from one point to another. They are used in an aircraft to maintain pressurization in cabin areas, to retain fuel in storage areas, to achieve exterior surface aerodynamic smoothness, and to weatherproof the airframe.

Sealants are used in general repair work in the field and for maintenance and restoration of seam integrity in critical areas if structural damage or the use of paint removers has loosened existing sealants.

Conditions surrounding the requirements for use of sealants govern the type of sealants to be used. Some sealants are exposed to extremely high and/or low temperatures. Other sealants are in contact with fuels, lubricants, etc. Therefore, it is necessary that sealants be used which have been compounded for that particular type of usage. These sealants are supplied in different consistencies and rates of cure. The basic types of sealants are classified in three general categories—Pliable Sealants, Drying Sealants, and Curing Sealants.

PLIABLE SEALANTS

These sealants are referred to as one-part and are supplied ready for use as packaged. They are solids and change little, if any, during or after application. Solvent is not used in this type. Therefore, drying is not necessary; and except for normal aging, they remain virtually the same as when first packaged, neither hardening nor shrinking. The adhesion to metal, glass, and plastic surfaces is excellent. Pliable sealants are used around high-usage access panels and doors, and in areas where pressurization cavities must be maintained.

DRYING SEALANTS

Drying sealants set and cure by evaporation of the solvent. Solvents are used in these sealants to provide the desired consistency for application. Consistency or hardness may change little or much when this type sealant dries, depending on the amount of solvent it contains. Shrinkage upon drying is another important consideration, and the degree of shrinkage is dependent upon the proportion of solvents.

CURING SEALANTS

Catalyst-cured sealants have obvious advantages over drying sealants because they are transformed from a fluid or semifluid state into a solid mass by chemical reaction or physical change, rather than by evaporation of a solvent. A chemical catalyst or "accelerator" is added and thoroughly mixed just prior to sealant applications. Heat may or may not be employed to speed up the curing process. When using a catalyst, accurate proprotioning and thorough mixing of the two components are vitally important to assure a complete and even cure.

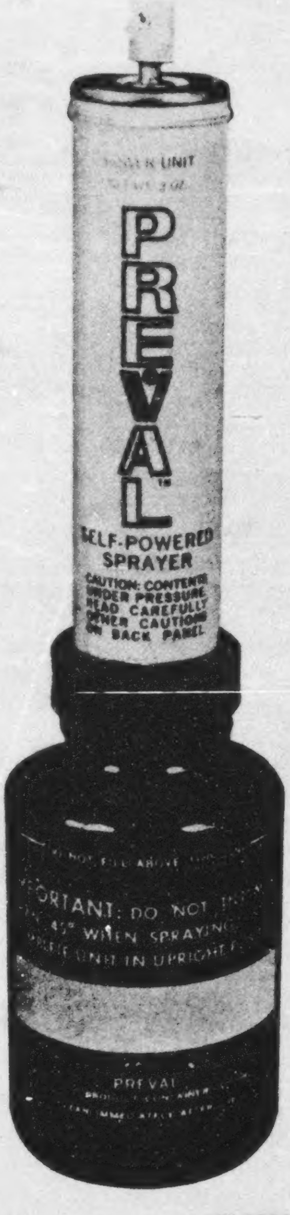
APPLICATION OF SEALANTS

Application of sealants varies according to time element, tools required, and the method of application. However, the following restrictions apply to all sealant applications:

1. Sealant should be used within the approximate application time limits specified by the sealant manufacturer.
2. Sealant should not be applied to metal which is colder than 70° F. Better adhesion is obtained and the applied sealant will have less tendency to flow out of place while curing if the metal is warmed to a temperature of 90° F to 100° F before the sealant is applied.
3. Sealant should be discarded immediately when it becomes too stiff to apply or work readily. Stiff or partially cured sealant will not wet the surface to which it is to be applied as well as fresh material and, consequently, will not have satisfactory adhesion.
4. Sealant should not be used for faying surface applications unless it has just been removed from refrigerated storage or freshly mixed.

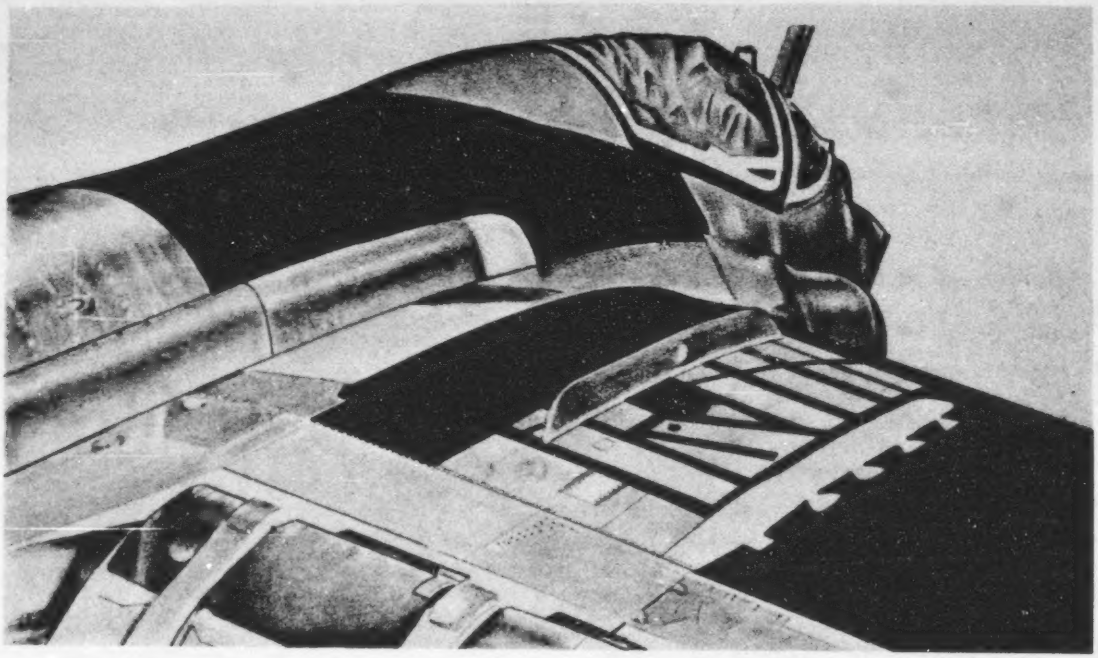
While the use of sealants on aircraft surfaces has greatly increased over the past few years, application methods have been mostly through the use of brushes, dipping, extrusion guns, and spatulas. The spraying of sealants has been a recent development. Sealant, MIL-S-81733, Type III, is the one most extensively used for spray application. If Type III sealant cannot be procured, sealant MIL-S-8802, Class A, may be used by thinning to a sprayable consistency by the addition of toluene.

In addition to standard spray type equipment, special application types have been developed for the occasional or small touchup job. There are many types available. Figure 11-31 illustrates one type which consists of a self-contained power unit with an attached spray bottle (sealant container). The essential features include the power unit with a pushbutton spray cap on top and on the bottom, and a screw-type lid which attaches to the sealant container. A



AM.1224

Figure 11-31.–Spray applicator kit.



AM.1225

Figure 11-32.—Sealant applied to aircraft exterior surfaces.

dip tube extends from the bottom of the power unit into the sealant container. The power unit, which may be procured separately, contains three ounces of propellant. The sealant container (spray bottle) can also be procured separately.

Figure 11-32 illustrates where sealant is applied to protect some of the most corrosion-prone areas on an A-6 aircraft. The sealant is applied using spray, spatula, and brush methods.

When pressure sealing an aircraft, the sealing materials should be applied in such a manner as to produce a continuous bead, film, or fillet over the sealed area. Air bubbles, voids, metal chips, or oily contamination will prevent an effective seal. Therefore, the success of the sealing operation depends upon the cleanliness of the area and the careful application of the sealant materials.

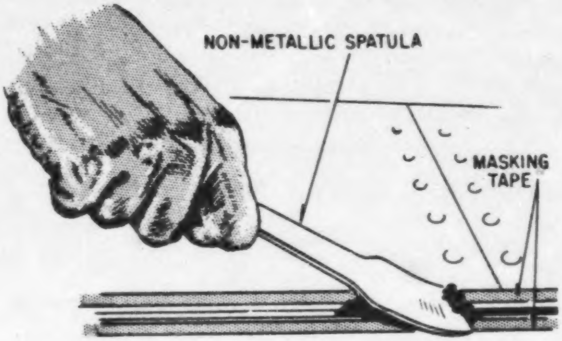
There are various methods of pressure sealing joints and seams in aircraft. The applicable Structural Repair Manual will specify the method to be used in each application.

The sealing of a faying surface is accomplished by brush coating the contacting surfaces with the specified sealant. The application of the sealant should be made immediately before fastening the parts together.

Careful planning and arrangement of work and equipment are necessary in order that faying surface seals on large assemblies may be closed within the application time limit of the sealant. Once the sealant has been applied, the parts must be joined, the required number of bolts must be torqued, and all the rivets driven within this time limit.

When insulating tape has been installed between the faying surfaces to prevent dissimilar metals contacts, pressure sealing should be accomplished by fillet sealing.

Fillet sealing is accomplished by spreading the specified sealant along the seam with a sealant injection gun. The sealant should be spread in approximately 3-foot increments. Before proceeding to the next increment, the applied portion of the fillet should be worked in with a sealant spatula or tool. (See fig. 11-33.) This working of the sealant is done to fill in all voids in the seam and to eliminate as many air bubbles as possible. The leak-free service life of the sealant is determined by the thoroughness and care used in working out the air bubbles.



AM.65

Figure 11-33.–Applying sealant.

After the sealant has cured to a tack-free condition, the fillet should be inspected for any remaining air bubbles. Such air bubbles should be opened up and filled with sealant.

When a heavy fillet is required it should be applied in layers and the top layer should fair with the metal.

Injection sealing is the pressure filling of openings or voids with a sealant injection gun. Joggles should be filled by forcing sealant into the opening until it emerges from the opposite side. Voids and cavities are filled by starting with the nozzle of the sealant injection gun at the bottom of the space and filling as the nozzle is withdrawn.

Fasteners such as rivets, Rivnuts, screws, and small bolts should have a brush coat of sealant over the protruding portion on the pressure side. Washers should have a brush coat of sealant on both sides. Split type grommets should have sealant brushed into the split prior to installation. After installation, fillets should be applied to both the base of the grommet and the protruding tube on the pressure side.

Sealing Compound (MIL-S-8802)

This temperature-resistant (-65° to +250° F), two-component, synthetic rubber compound is used for sealing and repairing fuel tanks and fuel cell cavities. It is produced in the following classifications:

Class A–Sealing material, suitable for brush application.

Class B–Sealing material, suitable for application by extrusion gun and spatula.

Class C–Sealing material, suitable for faying surface sealing.

Dash numbers after the classification code indicate the application time in hours allowed before the curing cycle will have progressed to the point where it is no longer feasible to apply that particular batch of sealant.

Class A dash numbers are -1/2 and -2.

Class B dash numbers are -1/2, -2, and -4.

Class C dash numbers are -20 and -80 (8 hours of application time with the remaining time allowed for working the material).

Example: Class A-2 designates a brushable material having an application time of 2 hours. Class B-1/2 designates an extrusion gun material having an application time of 1/2 hour. Class C-20 designates a faying surface sealant with an application time of 8 hours and a working life of 20 hours.

Sealing Compound (MIL-S-81733)

This accelerated, room temperature curing synthetic rubber compound is used in sealing metal components on weapons and aircraft systems for protection against corrosion. This sealant contains a percentage of magnesium chromate as a corrosion inhibitor. The classification of this sealant compound is of the following types:

Type I–For brush or dip application.

Type II–For extrusion application, gun or spatula.

Type III–For spray gun application.

Type IV–For faying surface application, gun or spatula.

The following dash numbers are used to designate the maximum application time in hours:

Type I–Dash numbers are -1/2 and -2.
Type II–Dash numbers are -1/2, -2, and -4.
Type III–Dash number is -1.
Type IV–Dash numbers are -12 and -24.

SAFETY PRECAUTIONS

Many of the sealants listed above may be flammable and/or may produce toxic vapors. When using any material designated as flammable, all sources of ignition must be at least 50 feet away from the location of the work. Toxic vapors are produced by the evaporation of solvents and/or the chemical reaction taking place in the curing sealants. When using sealants in confined spaces such as fuel cells, fuselage or wing sections, table or bench operations, etc., adequate local exhaust ventilation must be used to reduce the vapors below the maximum allowable concentration, and kept at that level until repairs have been completed. Do not eat or smoke when working with sealants.

CHAPTER 12

LINE OPERATIONS AND MAINTENANCE

Line operations and maintenance is one of the most important responsibilities of the AMS3 and AMS2. Line operations and maintenance is the term used to describe that work which is necessary to insure that operational aircraft, aircraft equipment, and aircraft support equipment are ready and safe for the type of flight or operations for which they are scheduled. This work is performed on a flight line, flight deck, or other place normally used to park aircraft. It is usually performed prior to or between scheduled flights, without removal of the aircraft from the flight schedule.

Line operations and maintenance includes aircraft handling, daily preflight and postflight inspections, servicing, lubrication, jacking, and the use and maintenance of various types of aircraft support equipment. Some of these functions are not normally performed by personnel of the AMS rating, however, many operating activities use third class petty officers of the AM and AD ratings as Plane Captains. As a plant captain, the AMS may be required to perform all of these functions.

AIRCRAFT HANDLING

Although aircraft handling is primarily the responsibility of the AB rating, all aircraft maintenance personnel should be familiar with proper ground handling techniques. Practically all structural damage to aircraft on the ground is caused by carelessness or lack of knowledge of proper ground handling procedures.

This section describes the duties of the taxi signalman and discusses some of the problems involved in towing, spotting, and securing aircraft.

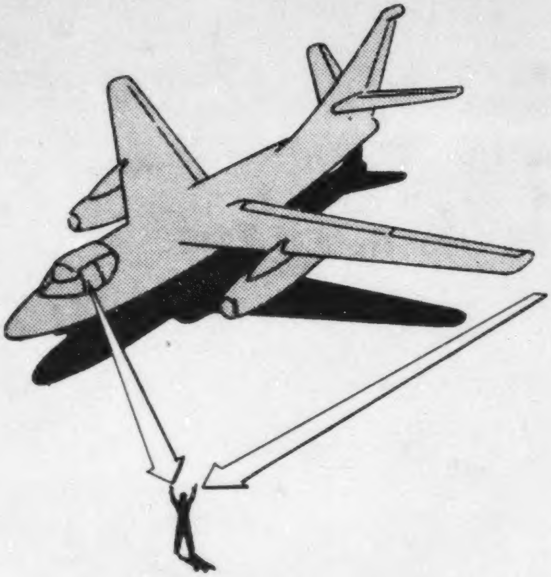
TAXI SIGNALMAN (PLANE DIRECTOR)

Any time an aircraft is ready to taxi from the flight line or is returning to the line for spotting, it is directed by one or more taxi signalmen as necessary.

The taxi signalman should assume and maintain a position where he can see the pilot's eyes at all times. If it is necessary for him to lose sight of the pilot's eyes in changing positions, or for any other reason, he should signal the pilot to stop until he has taken up his new position.

The taxi signalman has a definite position to maintain when directing aircraft, calculated to give him all possible advantages. His position when directing single-engine aircraft should be slightly ahead of the aircraft and in line with the left wingtip. An alternate position, in line with the right wingtip, may be used when it is necessary to clear obstructions.

When directing aircraft with side-by-side seating, such as is found on multiengine aircraft, his position is forward of the left wingtip. He has no alternate position since the pilot of a multiengine aircraft sits on the left-hand side of the cockpit. When directing multiengine aircraft in obstructed areas, an assistant taxi signalman may be used on the right wingtip. The assistant taxi signalman will signal the aircraft taxi signalman on the left wingtip. The taxi signalman must always be in a position to see the assistant taxi signalman and the pilot's eyes. Figure 12-1 illustrates the taxi signalman's position directing aircraft.



AM.190

Figure 12-1.—Position of taxi signalman.

When towing aircraft, the same positions are used as for directing an aircraft moving under its own power. The taxi signalman must keep the occupant of the cockpit (usually the plane captain), the driver of the towing vehicle, and assistant taxi signalmen in sight at all times.

Aircraft being taxied on land within 25 feet of obstructions must have a taxi signalman at each wingtip. If an obstruction is present on one side only, a man at that wingtip is required. Aircraft must not be taxied at any time within 5 feet of obstructions. Aircraft being taxied on water must not be taxied closer than 50 feet to obstructions except in mooring or docking procedures or when dictated by nature of the mission. Extra precaution is necessary when directing aircraft at night. The taxi strip and parking area should be inspected for workstands and any other mobile equipment which can damage an aircraft.

Standard Taxi Signals

Standard taxi signals are used by all branches of the Armed Forces so that there will be no misunderstanding when a taxi signalman of one service is signaling a pilot from another. These signals are for the most part given with the hands; at night plastic wands attached to regular flashlights are used. The signals should be definite and precise to eliminate any possible misunderstanding and to inspire the pilot's confidence in the taxi signalman.

The Airman Manual, NavPers 10307-C, chapter 12, lists and explains the standard taxi signals used by all branches of the Armed Forces for the operation and movement of aircraft on the ground, including helicopter landing, take-off, and ground handling signals.

Aircraft handling procedures and signals peculiar to shipboard operations which would be of interest to plane captains and other maintenance personnel assigned to the flight deck are listed in the CVA/CVS NATOPS Manual. A similar manual is provided for the use of personnel assigned to Amphibious Assault Ships (LPH).

The General Information section of each aircraft Maintenance Instructions Manual lists the necessary special signals required for that specific aircraft and not covered by the standard taxi signals.

TOWING AIRCRAFT

Towing aircraft can be a hazardous operation, causing damage to the aircraft and injury to personnel, if done recklessly or carelessly. The following paragraphs outline the general procedure for towing aircraft; however, specific instructions for each model of aircraft are detailed in the General Information section of the applicable Maintenance Instructions Manual and should be followed in all instances.

NOTE: Most naval aviation activities issue specific instructions concerning aircraft towing. These instructions usually contain the composition of the tow crew, tow tractor speed, and various other instructions concerning local conditions. These instructions must be complied with.

Aircraft are generally moved (towed) by a tow crew. The tow crew is usually composed of a tractor driver, a plane captain (to man the cockpit), and one man to watch for clearance at each wingtip and the tail.

The man assigned to operate the brakes must be thoroughly familiar with the particular type aircraft. His main function is to operate the brakes in case the tow bar should fail or come unhooked. He must also be familiar with the operation of various systems such as the ejection seat, power canopy, wing fold, and the safety precautions associated with each.

The men assigned to observe the wings and tail should proceed at their assigned stations as the aircraft is being towed. It is the responsibility of these men to keep a sharp lookout for obstructions and signal the tractor driver in time to prevent collisions. Signals may be given with the hands or a whistle.

Only qualified personnel should attempt to tow an aircraft. Driving a tow tractor requires specialized training as well as a valid Navy driver's license.

Tow Bars

There are two types of tow bars–universal and special. Special tow bars are those designed for use with only one type of aricraft. The universal tow bar is designed to tow a number of different types of naval aircraft.

The universal tow bar (NT-4) which is now being used by the Navy is shown in figure 12-2. This tow bar is designed with sufficient tensile strength to pull most aircraft, but is not intended to be subjected to torsional of twisting loads. Although the universal tow bar has small wheels that permit it to be towed behind the tow tractor when going to and from an aircraft, it will suffer less damage if it is loaded aboard the tow tractor and hauled to the aircraft. When the bar is attached to the aircraft, all engaging devices should be inspected for damage or malfunctions before moving the aircraft.

The universal tow bar, when used for nosewheel towing (fig. 12-3) is secured to the nosewheel axle by means of two pins and a tensioning chain and knob.

To mount the universal tow bar on a nosewheel, the tensioning knob is loosened and the chain is released. After the bars are lifted and the pins inserted into the axle ends, the chain is drawn tightly through the bar and hooked in the slot which is provided to lock it in

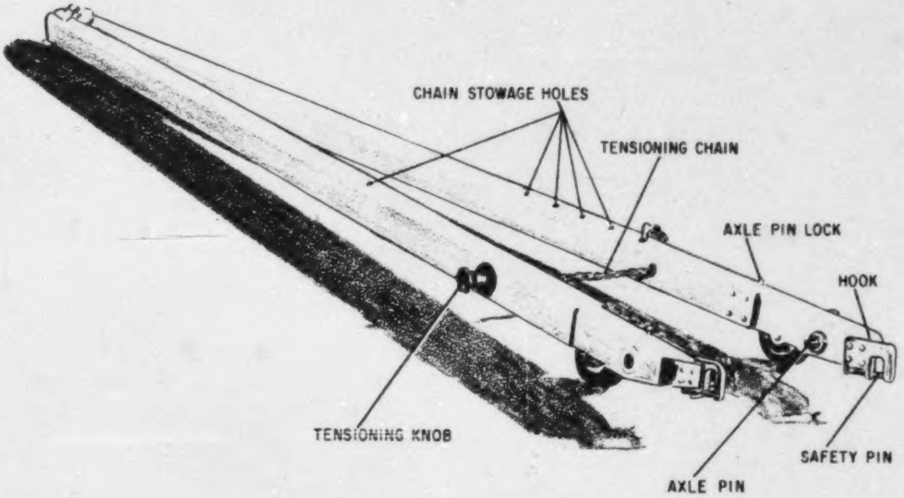
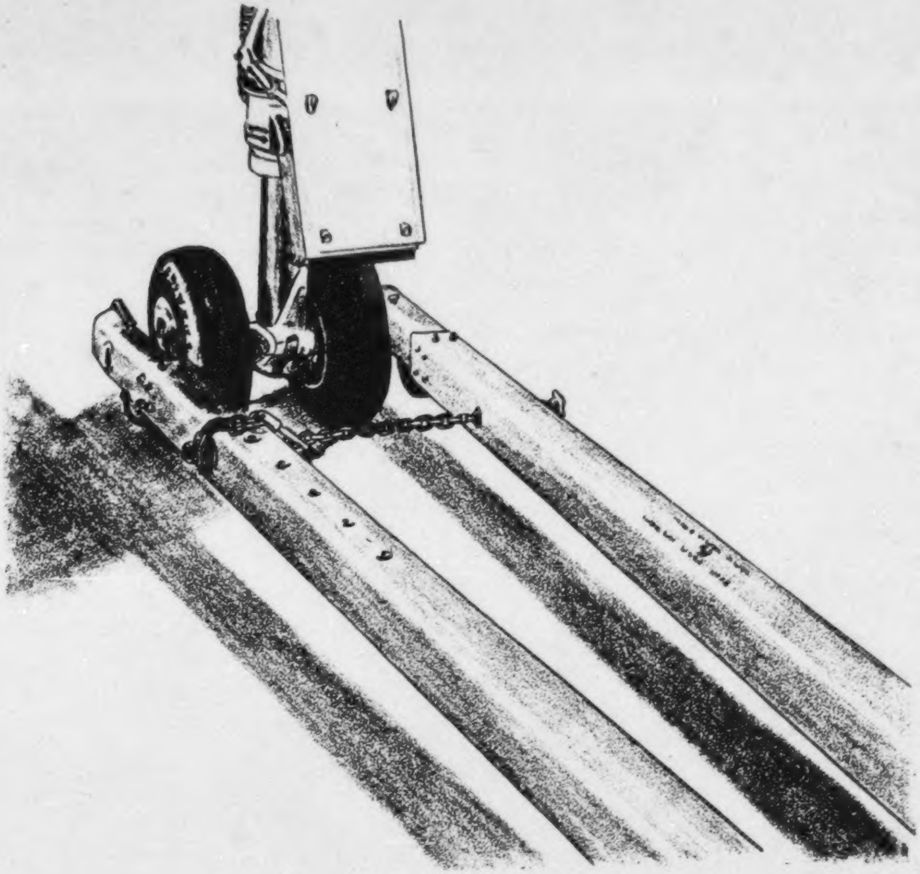


Figure 12-2.–Universal tow bar (NT-4).



AM.194

Figure 12-3.—NT-4 tow bar installed on nosewheel.

place. Tightening the tensioning knob then applies enough pressure to hold the bar pins in the ends of the axles.

Holes are provided in one bar to stow the pin on the loose end of the tensioning chain. Placing this pin in one of these stowage holes eliminates the possibility of damaging the chain by dragging it on the deck as the aircraft is being towed.

The universal tow bar may be used to tow aircraft from rings mounted on the fuselage or landing gear. The tow bar is secured to these rings by means of hooks which are mounted on the ends of the bars. A spring-loaded safety pin secures the hooks in the rings.

Special tow bars are designed to be secured to the aircraft in various ways. The information contained in the applicable Maintenance Instructions Manual should always be followed when attaching special tow bars to an aircraft.

When towing the aircraft, the towing vehicle speed must be reasonable, and all persons involved in the operation must be alert. Only reliable, competent personnel should be assigned to operate tow tractors. When the aircraft is spotted, the brakes of the tow tractor should not be relied upon to stop the aircraft. The man in the cockpit should be alert for the possible need of aircraft brakes along with those of the tow tractor.

NOTE: Before towing an aircraft, insure that all landing gear ground safety locks are installed. Landing gear ground safety locks are pins and clamps which are used to insure that the landing gear does not retract accidentally while ground handling the aircraft.

SPOTTING AIRCRAFT

An aircraft can be spotted on the flight line under its own power, by the use of a tow tractor, or manually, by pushing. If it is spotted manually, the handling crew should be instructed not to push on any control surfaces or other areas on the aircraft which are stenciled "no push," as damage to the aircraft may result. Regardless of the method used to spot the aircraft, a qualified man must be in the cockpit to operate the brakes.

A qualified signalman should also be used to direct the aircraft to its assigned spot. Sometimes the spots will be painted on the parking ramp, but in many cases he will have to be familiar with the parking area so he can spot the aircraft in the best position for securing it to the tiedown pad eyes. The position of the taxi signalman during spotting is the same as for taxiing, and he should be able to see the eyes of the man in the cockpit at all times.

When spotting aircraft at night, extra precautions should be taken to insure that the parking area is clear of all workstands and other equipment. Assistant taxi signalmen should be used at each wingtip to insure that the path is clear and that there is no danger of hitting other aircraft or obstructions.

When the aircraft is spotted in its proper position, the brakes should be applied and held until the main landing gear wheels are chocked.

AIRCRAFT TIEDOWN

The tiedown of aircraft is a very important part of ground handling. When tying down aircraft, the expected weather conditions will determine how the aircraft should be secured. The tiedown procedures provided in the General Information and Servicing volume of the applicable Maintenance Instructions Manual include normal weather tiedown procedures and heavy or severe weather tiedown procedures. Some MIM's also include special tiedown procedures to be used when jacking an aircraft aboard ship while the ship is underway. Figure 12-4 illustrates the severe weather and shipboard tiedown arrangement for the A-6A aircraft. One tiedown per fitting is designated as sufficient for normal weather tiedown.

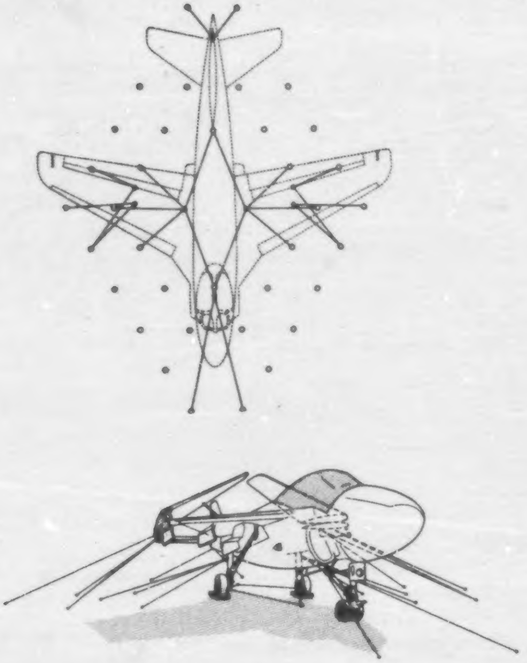
Carrier Aircraft Based Aboard Ship

Aircraft aboard carriers are tied to pad eyes which are welded into the flight deck and the hangar deck. These pad eyes are quite similar to the pad eyes found embedded in the concrete parking areas of naval air stations.

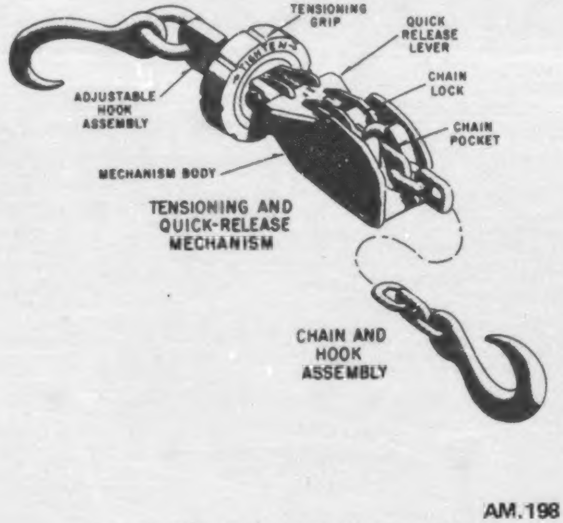
The tiedown of aircraft aboard aircraft carriers is practically the same as that specified for aircraft based ashore. However, since the carrier is subject to movement, the aircraft must be tied down securely as soon as it is parked. Most carriers require the use of at least three tiedowns as soon as it is parked and more if it is to be left unattended. The total number of tiedowns necessary depends upon the operating conditions. The General Information section of the aircraft Maintenance Instructions Manual contains information concerning tiedown points, type tiedowns to be used, and the number of tiedowns to be used on each aircraft. The Air Department of the carrier may have additional instructions which may require more tiedowns than specified in the applicable Maintenance Instructions Manual.

The tiedown commonly used aboard carriers is illustrated in figure 12-5. The chain type tiedown (TD-1) is used to secure aircraft aboard ships and ashore. It has a rated capacity of 10,000 pounds. Each TD-1 tiedown weighs about 12 pounds.

The TD-1 tiedown consists of a chain and a tensioning device. The chain is inserted into the tensioning device and locked by a spring-loaded lock. After the chain is locked in the tensioning device the tiedown may be tightened by turning



AM.1210
Figure 12-4.—Tiedown arrangement—A-6A.



AM.198
Figure 12-5.—Chain type tiedown—TD-1.

the tension nut in the direction of the arrow on the end of the nut. The TD-1 tiedown is released by pulling the release lever up and back.

Land and Carrier Aircraft Based Ashore

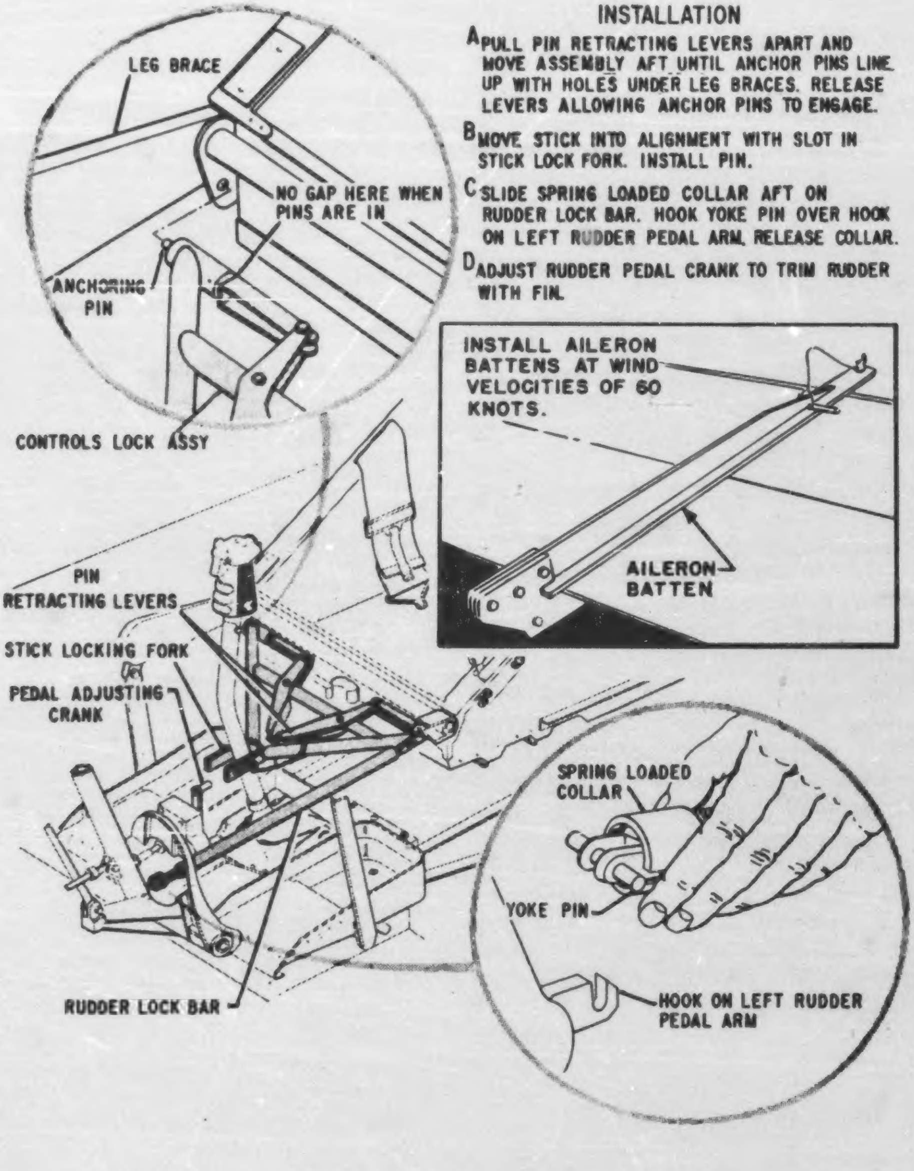
Aircraft ashore on naval air stations are tied down on concrete parking areas equipped with ringlike fittings called pad eyes. These pad eyes are installed when the concrete is poured and are installed flush with the surfaces of the concrete The aircraft to be tied down is spotted in the parking area in the best position for full utilization of the pad eyes. If high winds are anticipated, they should be headed into the wind. The aircraft may be tied down with chain type tiedowns or manila line.

When manila line is used, it should be whipped at one end and have an eye splice at the other. Put one end through the tiedown ring or point on the aircraft and the other end through the pad eye, thread the whipped end through the eye splice and tighten up on the line. Then secure the line, using half hitches or a rolling hitch together with half hitches.

CAUTION: When manila line is used, it should be carefully adjusted to provide for shrinkage due to moisture. However, excessive line slack which would allow shifting of the aircraft should be avoided.

The number of tiedown lines or chains to use when securing the aircraft is governed by the anticipated weather conditions. The normal and heavy weather tiedown procedures are given for each type aircraft in the applicable Maintenance Instructions Manual.

Most aircraft are equipped with surface control locks which should be engaged or installed whenever the aircraft is secured. Some aircraft control surfaces are locked by simply moving a lever and aligning the controls in the neutral position. However, some aircraft require the use of gust locks such as the one shown in figure 12-6. Since the method of locking controls will vary on different type aircraft, check the applicable Maintenance Instructions



INSTALLATION

A PULL PIN RETRACTING LEVERS APART AND MOVE ASSEMBLY AFT UNTIL ANCHOR PINS LINE UP WITH HOLES UNDER LEG BRACES. RELEASE LEVERS ALLOWING ANCHOR PINS TO ENGAGE.

B MOVE STICK INTO ALIGNMENT WITH SLOT IN STICK LOCK FORK. INSTALL PIN.

C SLIDE SPRING LOADED COLLAR AFT ON RUDDER LOCK BAR. HOOK YOKE PIN OVER HOOK ON LEFT RUDDER PEDAL ARM. RELEASE COLLAR.

D ADJUST RUDDER PEDAL CRANK TO TRIM RUDDER WITH FIN.

INSTALL AILERON BATTENS AT WIND VELOCITIES OF 60 KNOTS.

AM.197

Figure 12-6.—Surface control locking device and batten installation.

Manual for the proper installation or engaging procedure.

When extremely high winds are anticipated and the aircraft cannot be moved into the hangar, the aircraft should be turned so that it faces into the wind. All covers and guards which protect the canopy, wing butts, air intakes and other parts of the aircraft should be installed.

These protective covers should also be installed if the aircraft is to remain secured on the line for any length of time.

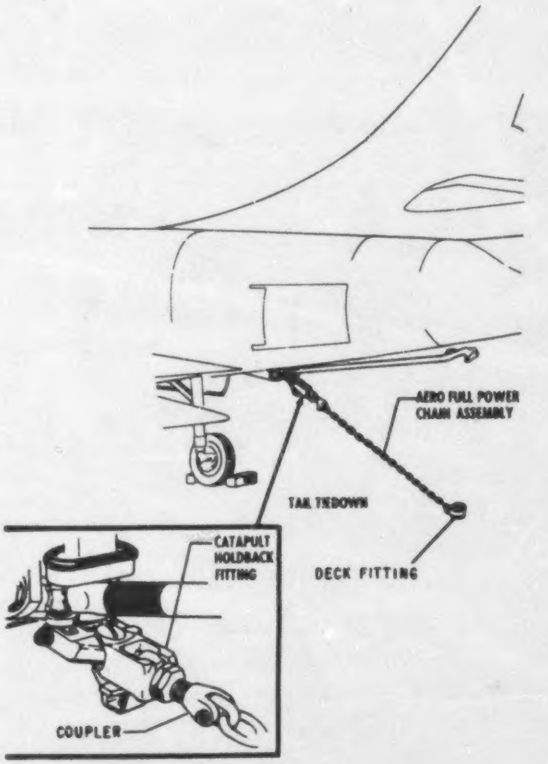
A special heavy-duty tiedown (fig. 12-7) commonly referred to as a full power chain assembly is used to secure the aircraft to the deck while the engine is being run up to full power for check and adjustments.

The full power tiedown assembly consists of a coupler, chain and a deck fitting. The coupler adapts to the catapult holdback fitting on the aircraft. The chain is made of welded links and is attached to the coupler and deck fitting with removable shackles. The deck fitting assembly permits 360 degrees horizontal travel around the deck and 0 to 45 degrees vertical angle from the deck. The deck fitting assembly adapts to the various types of pad eyes.

Only specifically tested and designated pad eyes should be utilized for high power turnups. In other words, all pad eyes that will accommodate the full power chain assembly should not be considered strong enough to withstand the stress of a full power turnup.

When carrier aircraft are tied down with their wings folded, a jury strut which gives extra support to the folded part of the wing must be installed. When aircraft must be left on the flight deck of a carrier in extremely heavy weather (winds in excess of 100 knots), the wings should be left in the spread position.

Aircraft are spotted and tied down aboard the carrier with just inches between each aircraft. Therefore, it is of utmost importance that they be secured properly to prevent any excessive movement when the ship is maneuvering or encountering heavy seas. Excessive movement of just one aircraft may cause serious damage to several aircraft.



AM.199

Figure 12-7.—Full power tiedown.

USE OF COVERS AND SHROUDS

Protective covers and shrouds are provided by the aircraft manufacturer for each aircraft. These covers are designed to protect various areas and components of the aircraft from the elements, to protect personnel, and to prevent foreign objects from entering vital areas during periods of extended inactivity. The applicable Maintenance Instructions Manual contains information concerning the installation of covers and protective devices. Protective covers are usually provided for canopies, engine air intakes and exhausts, wing and vertical stabilizer fold areas, and various other ducts or inlets.

Protective covers should be tightly installed. All straps and locking devices should be secured. Loose ends should not be left to blow in the wind. The loose end of a strap, particularly one with a metal clip or buckle, will severely damage the finish of an aircraft.

Care should be taken when handling protective covers to insure that grit or trash does not collect on the inner liner. The installation of a dirty cover may scratch the finish of the aircraft or severely damage transparent plastic canopies and glass windshields.

All protective covers should be installed in such a manner that free drainage is assured. Care should be taken not to create an area which will trap and hold salt water. Covers may also act as a green house in warm weather and cause collection and condensation of moisture underneath. Covers should be loosened or removed and the aircraft ventilated on warm sunny days.

FLIGHT LINE SAFETY PRECAUTIONS

In addition to the more specific safety precautions presented in various other chapters and in other sections of this chapter, there are a number of miscellaneous precautions which must be observed when working on the aircraft flight line. The following are especially important.

Intake Duct Hazards

When working with reciprocating engine aircraft, the propeller represents the greatest single hazard to personal safety; however, the jet engine presents several major hazards. The air intake duct of operating jet engines represents an everpresent hazard to both personnel working near the inlet duct of the aircraft and to the engine itself if the turnup area around the front of the aircraft is not kept clear of debris. This hazard is, of course, greatest during maximum power settings.

The air inlet duct may develop enough suction to pull hats, eyeglasses, loose clothing, and rags from pockets. All loose articles should be made secure or removed before working around the engine. In some engines the suction is strong enough to pull a man up to, or partially into the inlet. Needless to say, precautions must be taken to keep clear of the inlet.

Protective screens are supplied as part of the ground handling equipment for most jet aircraft. These screens should be installed prior to all maintenance turnups.

Exhaust Area Hazards

Jet engine exhaust creates several hazards. Tests show that the carbon monoxide content of jet exhaust is low; however, other gases are present which are irritating to the eyes. Less noticeable, but important, is the respiratory irritation which may be caused.

The two most important hazards of jet engine exhaust are the high temperature and high velocity of the exhaust gases from the tailpipe. High temperatures will be found up to several hundred feet from the tailpipe, depending on wind conditions. Closer to the aircraft, these temperatures are high enough to deteriorate bituminous pavement.

Quite frequently when a jet engine is being started, excess fuel accumulates in the tailpipe; when the fuel ignites, long flames are blown out of the tailpipe. The possibilities of this hazard should be known by flight line personnel and all flammable materials should be kept clear of the danger area.

During maximum power settings, the high velocity of the exhaust gases may pick up and blow loose dirt, sizable rocks, sand, and debris several hundred feet. Therefore, due caution should be used in parking an aircraft for runup. The General Information section of the applicable Maintenance Instructions Manual contains information concerning the exhaust area hazards. These instructions should be strictly adhered to. NO ONE should foolishly experiment with the safety margins specified.

After engine operation, no work should be done to the exhaust section for at least one-half hour (preferably longer). If work is necessary immediately, asbestos gloves must be worn.

Engine Noise

Modern jet engines produce noise capable of causing temporary as well as permanent loss of high frequency hearing. The proper precautions are as follows:

1. Wear the proper ear protection (earplugs and/or sound attenuators).
2. Do not exceed the time limits on exposure to the various sound intensities.
3. Have periodic checks on hearing ability.

Engine noise is broadcast from the aircraft in patterns which vary in direction, distance, and intensity with engine speed. Generally, the most intense sound areas are in the shape of two lobes extending out and aft from the aircraft centerline. However, dangerous intensities are also present to the side and forward of the aircraft.

Damage to hearing occurs when the ear is exposed to high sound intensities for excessive periods. The higher the sound intensities, the shorter is the period of exposure which will produce damage. Above 140 db sound intensity, any exposure without ear protection can cause damage.

NOTE: Sound intensity is measured in decibels (db). A decibel is a number which relates a given sound intensity to the smallest intensity that the average person can hear.

The wearing of regulation ear protection (earplugs and/or sound attenuators) will raise the limits of time exposure. All personnel working within danger areas should be familiar with calculated db levels (as specified in the applicable Maintenance Instructions Manual) and should wear the necessary protective equipment.

Movable Surface Hazards

Movable surfaces such as flight control surfaces, speed brakes, power operated canopies, and landing gear doors constitute a major hazard to flight line personnel. These units are normally operated during ground operations and maintenance. Therefore, care should be taken to insure that all personnel and equipment are clear of the area before operating any movable surface.

Power operated canopies have safety locks which must be installed during ground handling operations. These safety locks prevent the accidental closing of the canopy and this eliminates the possibility of personnel being crushed as the canopy closes.

The General Information and Servicing section of each Maintenance Instructions Manual contains specific information concerning the various movable surface hazards and specifies the safety locks which must be used. Personnel involved with line operations and maintenance should pay particular attention to this information since some of these units move extremely fast and with terrific power.

Seat Ejection Mechanisms

All safety precautions must be strictly observed when working around aircraft equipped with an ejection seat. These safety precautions cannot be overemphasized, as accidental actuation of the firing mechanism can result in death or serious injury to anyone in the cockpit area.

Each ejection seat has several ground safety pins, the exact number depending upon the type of seat. These safety pins are provided on redflagged lanyards for use at every point of potential danger. They must be installed whenever the aircraft is on the ground or deck, and must never be removed until the aircraft is ready for flight.

The following general precautions should always be kept in mind:

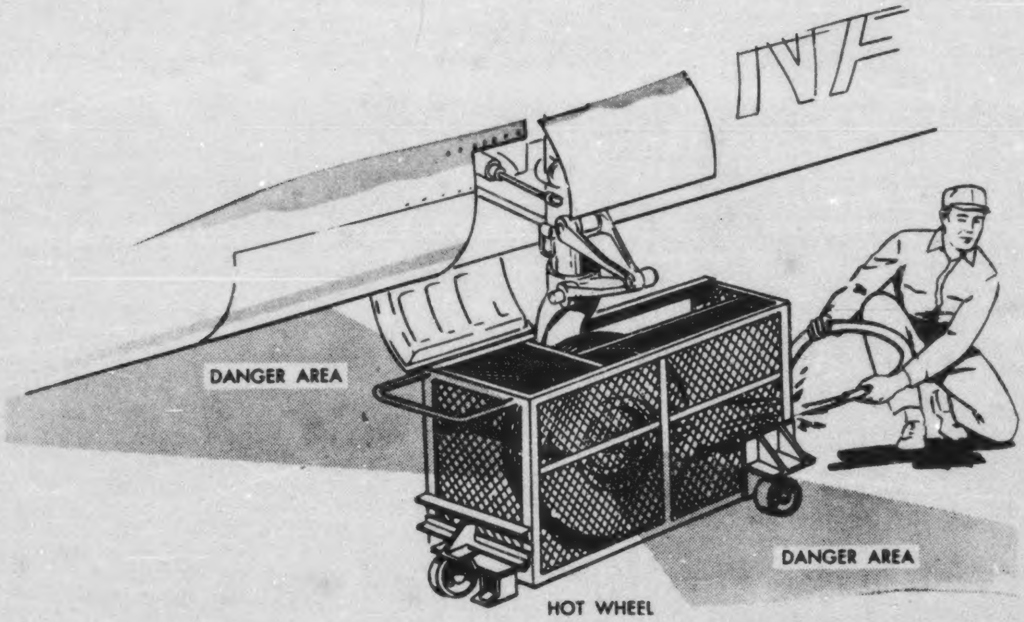
1. Ejection seats must be treated with the same respect as a loaded gun.
2. Always consider an ejection seat system loaded and armed.
3. Before entering a cockpit, know where the ejection seat safety pins are and be certain of their installation.
4. Only authorized personnel may work on ejection seats and components and only in an authorized area.

Overheated Wheel Brakes

In the event an aircraft has been subjected to excessive braking, the wheels may be heated to the point where there is danger of a blowout or fire. NOTE: Excessive brake heating weakens tire and wheel structure, increases tire pressure, and creates the possibility of fire in the magnesium wheel. When the brakes on an aircraft have been used excessively, the fire department should be notified immediately and all unnecessary personnel should be advised to leave the immediate area.

If blowout screens such as the one shown in figure 12-8 are available, they should be placed around both main wheels. These screens help to eliminate the possibility of damage or injury in the event of a blowout.

Upon sudden cooling, an overheated wheel may fracture of fly apart, which would hurl



AM.200

Figure 12-8.–Use of blowout screen on overheated brakes.

bolts or fragments through the air with sufficient speed to injure personnel. If the tire is flat, explosive failure of the wheel or tire will not result.

Required personnel should approach overheated wheels with extreme caution in the fore or aft directions–never in line with the axle.

CAUTION: The area on both sides of the tire and wheel, in line with the axle, is where the fragments would be hurled if the tire were to explode and is therefore called the danger area (fig. 12-8).

Heat transfer to the wheel will continue for some period of time until the brake is cooled. Therefore, the danger of explosive failure may exist after the aircraft is secured if action is not taken to cool the overheated brake.

NOTE: When a wheel/brake assembly overheats, making rapid deflation of aircraft tires necessary to prevent a wheel assembly explosion, ground personnel should direct the pilot to taxi the aircraft over a tire blowout board to puncture the tires and release their pressure. (See fig. 12-9.)

The recommended procedure for cooling overheated wheel, brake, and tire assemblies is to park the aircraft in an isolated location. Then allow the assembly to cool in ambient air. The use of cooling agents to accelerate cooling is not recommended unless operational necessity dictates their use. The application of the agents exposes personnel to danger by requiring their presence near the overheated assembly. However, if it is necessary to accelerate cooling, a straight stream of water or fog is recommended.

The water should be applied in 10- to 15-second periodic bursts, not in a continuous discharge. Each application should be separated by a waiting period of at least 30 to 60 seconds. A minimum of 3 to 5 applications is usually necessary.

When fog is used, the fog is deflected to the brake side of the wheel for a period of 5 to 10 seconds. Each application should be separated

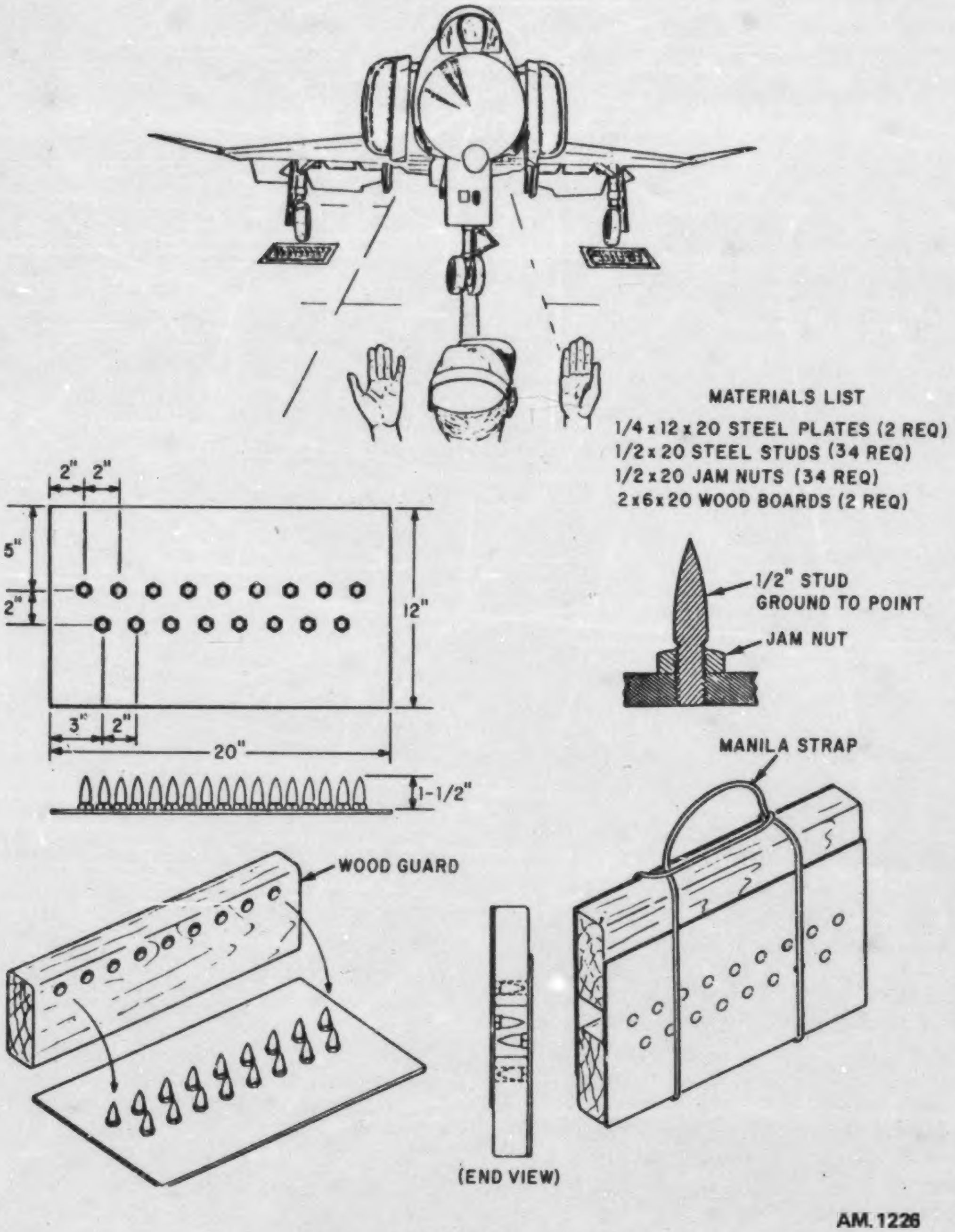

MATERIALS LIST
1/4 x 12 x 20 STEEL PLATES (2 REQ)
1/2 x 20 STEEL STUDS (34 REQ)
1/2 x 20 JAM NUTS (34 REQ)
2 x 6 x 20 WOOD BOARDS (2 REQ)
2"
2"
5"
2"
12"
3"
2"
20"
1-1/2"
1/2" STUD GROUND TO POINT
JAM NUT
MANILA STRAP
WOOD GUARD
(END VIEW)
AM.1226

Figure 12-9.—Emergency tire deflator.

by a waiting period of at least 20 seconds. This method is applied as long as it is necessary to control the temperature of the affected assembly. Never use CO_2 for cooling.

Once the brake has been properly cooled, permit the wheel to cool in ambient air. A crosswind or forced air from a blower or fan will assist in cooling the wheel.

The aircraft should not be moved for at least 15 minutes following cooling operations.

FLIGHT DECK SAFETY PRECAUTIONS

The flight deck of an aircraft carrier is one of the most hazardous places in the world and one of the busiest during launching, recovery, and respotting of aircraft. Plane captains and other maintenance personnel assigned specific duties associated with the flight deck must be constantly aware of this dangerous environment.

The predeployment training lectures for such personnel should include shipboard handling procedures, flight and hangar deck safety precautions, responsibilities during launch and recovery of aircraft, tiedown requirements and techniques, and special shipboard maintenance procedures and safety precautions. This training requirement is in addition to the general indoctrination given all personnel concerning flight quarters, general quarters, fire, abandon ship, man overboard, and other general drills; ship conditions, smoking and safety precautions and watch standing requirements peculiar to shipboard operations.

The previously discussed flight line safety precautions are applicable to flight deck operations. The primary difference is that because of the limited space and tempo of operations experienced on the flight deck the situation is increasingly more dangerous.

During launching and recovery of aircraft all personnel not required by such operations should leave the flight deck and catwalk areas. The safe parking area aft of the island is an unauthorized space for personnel during aircraft recovery. Personnel should not stand in or otherwise block entrances to the island structure or exits leading off the catwalks. Never turn your back on aircraft taxiing on the flight deck. Be alert for the unexpected at all times. There is no room for carelessness, daydreaming, or skylarking on the flight deck at any time.

All personnel assigned flight quarters on or above the hangar deck must wear appropriate jerseys and helmets. Personnel on the flight deck during flight quarters must wear the cranial impact helmet or its equivalent, goggles, sound attenuators, flight deck shoes, flotation gear, and an adequately secured whistle and survival light.

Any maintenance performed on aircraft which will require wingspread/fold, respot, turnup, blade track, jacking, etc., or maintenance that will prevent the aircraft from being moved regardless of how much or how little time is required for the work to be performed must take into consideration the fact that approval to proceed with such maintenance actions must be approved through the activity's Maintenance Control. The activity's Maintenance Control, before it can grant approval, must have obtained permission from the Aircraft Handling Officer via the Air Wing/Group Maintenance Liaison Officer or his representative.

When participating in aircraft turnup or jacking operations make sure that the permission of the Aircraft Handling Officer has been received as previously stated and that all ship's regulations are observed. Safety men with sufficient line to block off the area must be stationed around the aircraft.

Each ship may have safety precautions unique to that ship due to special circumstances and operational requirements. Petty officers are charged with the responsibility of knowing and enforcing those that apply to their area of work and their men.

ARMED AIRCRAFT PRECAUTIONS

Maintenance personnel must remain alert to the potential danger of the weapons utilized on the various types of aircraft. Shore stations utilize a specified area for arming and dearming aircraft. Aircraft returning from flights with hung weapons are required to be dearmed (by qualified Aviation Ordancemen) in the landing area or just clear of the landing area. If forward firing weapons are involved the aircraft must be stopped with a clear area ahead of the aircraft and dearmed prior to taxiing into designated recovery spots. All aircraft landing with unexpended weapons should be dearmed as soon as possible in ALL cases prior to commencement of any postflight checks, servicing, or refueling of the aircraft.

PREVENTION OF FOREIGN OBJECT DAMAGE TO JET ENGINES

Foreign object damage is an ever-present hazard to the operation of jet engines. It is the responsibility of all aircraft maintenance personnel to conscientiously adhere to and follow preventive procedures and policies to eliminate ingestion of foreign objects by jet engines. Several areas of concern are parking and storage areas and procedures, engine installation, and engine ground operation. Frequent and periodic inspection of engine nacelles, inlet ducts, and storage areas is recommended. When required, careful cleaning of these areas should be accomplished. All maintenance personnel must exercise extreme care while performing maintenance procedures in and around the aircraft to prevent foreign object damage to the engines. The greater size of the newer jet engines creates greater suction pressures and larger suction areas. The higher suction pressures enable the engines to pull objects from greater distances into the engines compressor section. Objects may be picked up from the deck areas or from some areas within the aircraft which are directly or indirectly open to the engine bay or intake duct. Therefore, it is mandatory that personnel performing maintenance in and around the aircraft account for all tools, hardware, and components after all maintenance procedures and operations.

The turnup and taxi area of the jet engine must be cleaned frequently to insure that the area is free of such foreign objects as nuts, bolts, washers, tools, cotter pins, safety wire, stones, rags, etc. Numerous jet engines have been completely demolished because someone failed to police the turnup and taxi area for loose gear before the engine was started.

Anyone working in the vicinity of jet aircraft should insure that all personal effects such as hats, gloves, pens, and cigarette lighters are secured. These items may also cause foreign object damage.

EXTINGUISHING FIRES DURING GROUND TURNUP

At air stations or aboard a carrier, experienced crash crews and fire crews are readily available. The need for the services of the fire crews can, in most cases, be avoided by the prompt and efficient use of firefighting equipment which is available at all times on the flight line. It is of the utmost importance that every man working on the line be familiar with the location and use of the firefighting equipment.

CO_2 bottles are the most common fire extinguishers used on the line. These bottles contain a sufficient quantity of CO_2 to handle most small fires started on the flight line. An aircraft should never be fueled, defueled, or its engines started without having one or more men standing by with CO_2 bottles.

Some aircraft carry one or more small CO_2 bottles. These bottles are intended for use in flight and should never be used in ground operations except in extreme emergency. In the event that they are used, they should be replaced prior to the aircraft's next flight.

Whenever an engine is started, personnel with adequate fire extinguishers must always be maintained in the immediate vicinity of the engine. When available, a 15-pound CO_2 fire extinguisher is the minimum which should be used when starting an engine.

Firefighting Procedure

If a fire starts in the tailpipe of a turbojet engine as it is being started, the engine should be given a dry start; that is, a start (motoring of the engine) with the switches which control the fuel in the OFF and CLOSED position.

If the fire persists, CO_2 can be discharged into the inlet duct so that it can be drawn through the engine while it is being given the dry run. CO_2 should not be discharged directly into the engine exhausts as this may damage the engine.

In case the fire is on the ground under the engine overboard drain, the CO_2 should be discharged on the ground rather than on the engine. This holds true also if the fire is at the tailpipe and the fuel is dripping to the ground and burning.

The methods described here are for emergency use only, because the fire department should always be notified when there is a fire in or near an aircraft. If the fire cannot be extinguished with the equipment at the scene, secure all switches, abandon the aircraft and stand by to assist the fire department upon their arrival.

AIRCRAFT SERVICING

Servicing of aircraft includes replenishing of the fuel, oil, hydraulic fluid, and other consumable materials. Also included under this heading are checking the tires for proper inflation, struts for proper extension, and the various air storage units for proper pressure.

NOTE: All aircraft servicing should be performed in accordance with the applicable set of Maintenance Requirement Cards. The set of cards covering the daily inspection contains the servicing instructions for each system. Further instructions concerning servicing may be found in the applicable Maintenance Instructions Manual.

FUEL REPLENISHMENT

Identification of Aircraft Fuels

Aircraft engine fuels currently in use are classified into types and grades as follows:

1. Reciprocating engine fuels; i.e., AVGAS (aviation gasoline).

GRADE	NATO SYMBOL	COLOR
80/87	F-12	Red
91/96	F-15	Blue
100/130	F-18	Green
115/145	F-22	Purple

2. Turbine engine fuels; i.e., JP (jet fuel).

GRADE	NATO SYMBOL	DESCRIPTION
JP-4	F-40	Low vapor pressure type.
JP-5	F-44	High flashpoint kerosene type.

The NATO symbol is a code number assigned to a product after it has been classified as standardized between two or more countries. No product is allocated more than one NATO symbol, and a number once assigned is never used for any other product. The NATO symbol is clearly distinguishable from all other markings; for example F-22 will be used by all NATO countries to identify 115/145 aviation gasoline.

Refueling Safety Precautions

Aviation gasoline is a highly volatile liquid which gives off a vapor. This aircraft fuel vapor is heavier than air and will settle to the ground, accumulating in dangerous amounts in depressions, troughs, or pits; and when combined with air in the proper proportions, forms an explosive mixture.

The ignition of vapor from aircraft fuel may occur from static sparks, sparks from tools, hot exhaust pipes, lighted cigarettes, electrical devices, and similar sources. A violent explosion followed by fire will result if liquid gasoline is present.

On the other hand, fuels such as JP-4 have some of the same characteristics of gasoline, but by no means the same substance. Different characteristics such as lower vapor pressure and high aromatic content exist in this fuel; therefore, special precautions in its handling must be taken.

All existing fire precautions must be adhered to during the fueling process. Smoking is not permitted in the aircraft during fueling. Also, no smoking or naked lights (such as are produced by oil lanterns, candles, matches, exposed electric switches, sliprings or commutators, a dynamo or motor, any spark-producing electrical equipment, or any burning material) are permitted within 100 feet of an aircraft being refueled, or of fuel storage tanks. No lights other than approved explosion-proof lights are permitted within 50 feet of these operations, and no light of any sort may be placed where it may come in contact with spilled fuel. Warning signs should be posted as a precautionary measure.

All accidental spillage of aircraft fuels or other combustible liquids must be immediately removed by washing, covered with a foam blanket to prevent ignition, or neutralized by other means. The proper fire authorities must be notified any time a large amount of aviation fuel is spilled.

Aircraft fuel tanks must be filled, purged, or have an inert gas (such as CO_2) over the gas in the tanks before storing aircraft in hangars, since this leaves no space for explosive vapors to form.

Nonspark tools must be used when working on any part of a system or unit designed for storing or handling combustible liquids.

The use of leaky tanks or fuel lines is not permitted. Repairs must be made on discovery, with due regard to the hazard involved.

Gasoline must be strained if there is the slightest chance that water may be present in the fuel. Most fueling trucks and underground storage systems have filter/separators which automatically filter water out of the gasoline before delivering it to the aircraft tank. These filter/separators should be checked daily for dirt and water. This system serves the same purpose as the sediment bulb or tank in an automobile gasoline system.

Aircraft should be fueled in a safe place. Do not fuel or defuel an aircraft in a hangar or other enclosed space except in case of emergency. Aircraft should be free from fire hazards, have engine switches off, and chocks placed under the wheels prior to fueling or defueling.

As an AMS striker, one of your duties might be standing by with a CO_2 fire extinguisher or other firefighting equipment while the aircraft is being refueled. The AMS striker assigned to stand by the fire extinguisher should insure that the extinguisher is full (by inspecting for the lead seat on the release mechanism) and that he is familiar with the release mechanism on the type extinguisher in use. When fighting a fuel fire it is most important that action be taken immediately; therefore, the fire watch should be alert at all times.

CAUTION: Guard against breathing hydrocarbon (fuel) vapors as they may cause sickness or may even be fatal. Do not let fumes accumulate—use adequate ventilating measures. Also, avoid getting fuel on clothes, skin, or in the eyes, because of the high lead content. Fuel-saturated clothing should be removed as soon as possible, and the parts of the body exposed to fuel washed thoroughly with soap and water. Wearing clothing saturated with fuel creates a dangerous fire hazard, and painful blisters may be caused by direct contact with fuel in the same manner as fire burns. When fuel has entered the eyes, medical attention should be obtained immediately.

When an aircraft is to be fueled by a truck, it should not be located in the vicinity of possible sources of ignition such as grinding, drilling, or welding operations. When practicable, a minimum of 50 feet from other aircraft or structures and 75 feet from any operating radar set should be maintained. Consideration must be given to the direction of the wind so that fuel vapors will not be carried toward a source of ignition.

The tank truck should be driven to a point as distant from the aircraft as the length of the hose permits, and preferably to the windward (upwind) side of the aircraft. It must be parked parallel to or heading away from the wing, or in such a position that it may be driven away quickly in the event of fire. As soon as the fueling operation has been completed, the truck should be removed from the aircraft's vicinity. The truck manway covers should be kept closed, except when a tank is actually being loaded, or when pumping fuel at 25°F or below, because at such temperatures vent valves may be inoperative.

NOTE: The operation of fuel trucks at many air stations is performed by civilian crews. Even though the Aviation Structural Mechanic S may not be called on to operate or drive fuel trucks, he must be thoroughly familiar with the entire procedure to insure safety of the fueling operation, in which he will be involved frequently.

Refueling crews usually include a minimum of three men. One person stands by with the firefighting equipment; another stays with the truck; and the third man handles the fuel hose at the aircraft and fills the tanks. A member of the crew makes sure that both the aircraft and the truck are properly grounded to prevent sparks from static electricity. A check should be made to see that all radio equipment and unnecessary electrical switches are turned off. Outside electrical power should not be connected to the aircraft unless it is necessary to operate the equipment involved with refueling. Care should be taken to identify the aviation fuel before beginning the refueling operation. Refueling trucks have the type fuel contained in the tanks painted across the side of the tank in black letters. An AMS who is involved with servicing aircraft should become familiar with the various grades of fuel and the aircraft's fuel requirements in order to insure that the appropriate fuel is always used.

Gravity Fueling

Many naval aircraft are refueled by the gravity fueling system. (See fig. 12-10) Some aircraft may be refueled by either the gravity or pressure fueling system and other aircraft are fueled from a single point by the pressure fueling system.

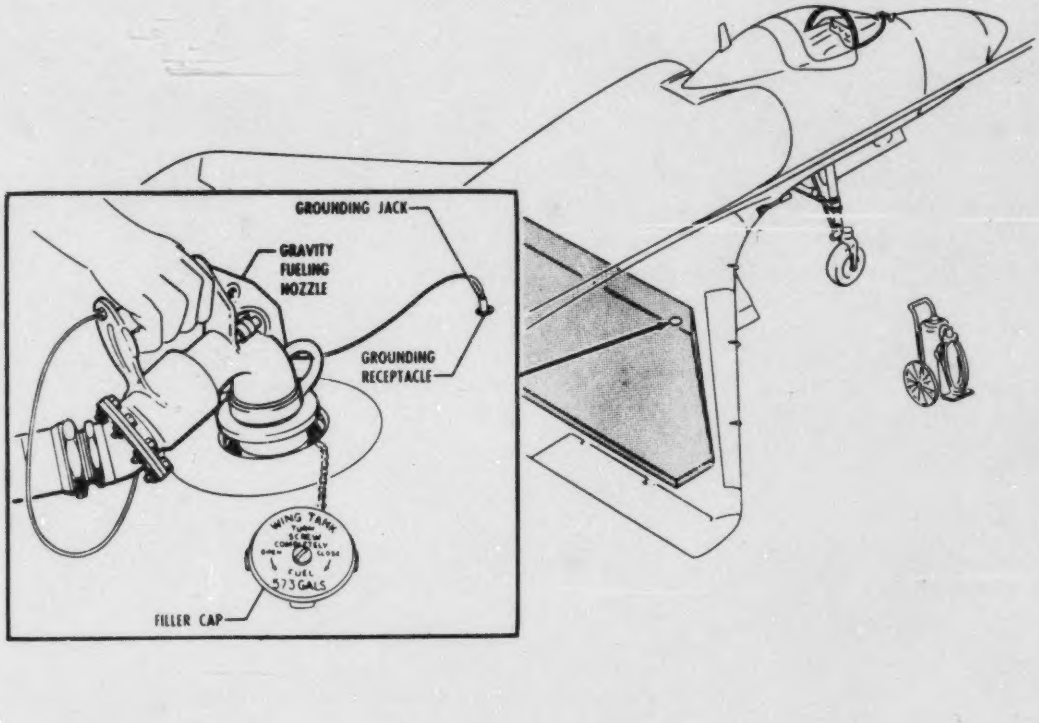
Gravity fueling is accomplished by grounding the nozzle, inserting the nozzle in the cell filler neck, and filling the tank to the bottom of the filler port neck.

The nozzle should always be grounded prior to being placed in the filler neck in order to prevent sparks caused by static electricity. The nozzle should be supported while in the filler neck to prevent damage to the filler neck and in the case of aircraft which use bladder type fuel cells (cells made from a type of rubberized nylon cloth) to prevent the possibility of damaging the cell with the end of the nozzle.

Pressure Fueling

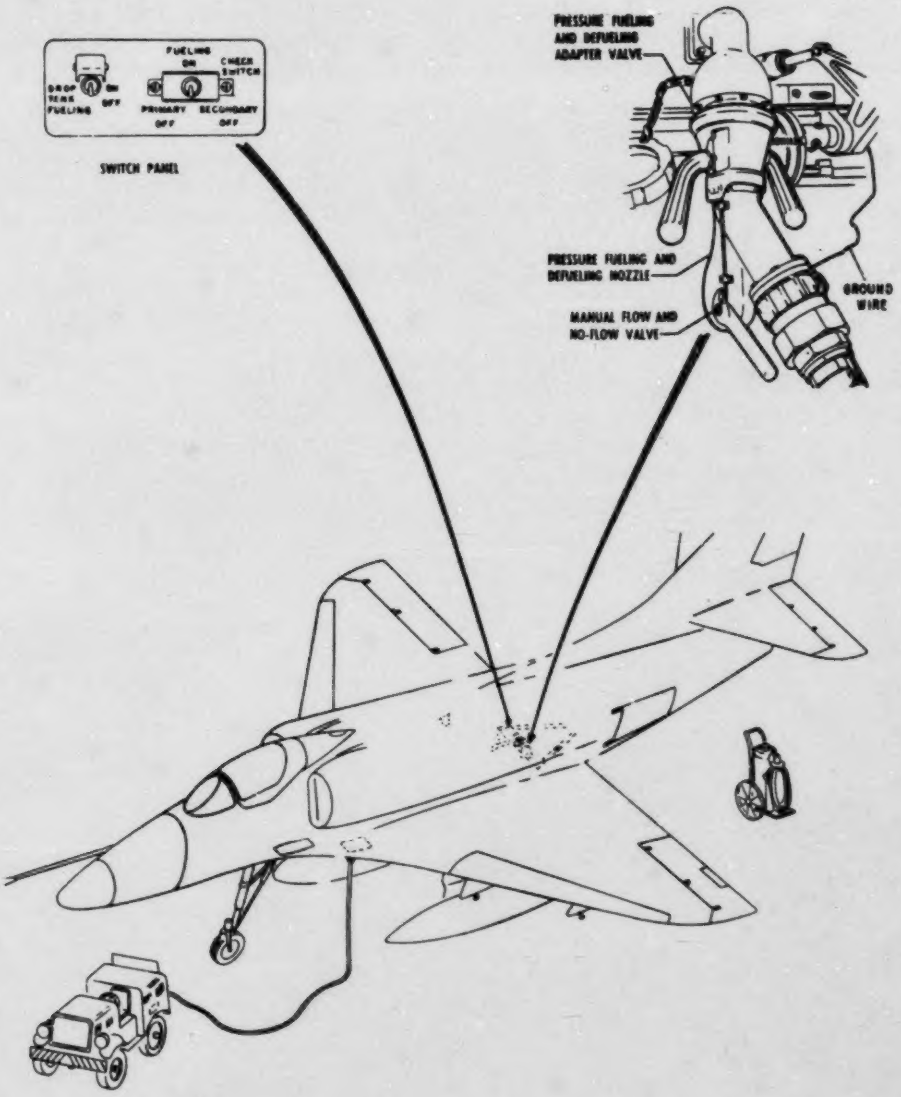
Most of the newer naval aircraft are refueled by the pressure fueling system. This system is employed to enable faster "operational turn around" of the aircraft.

Pressure fueling is usually accomplished from a single point. Fuel from this point is supplied to the various wing and fuselage tanks. In some



AM.201

Figure 12-10.—Gravity fueling.


FUELING
ON
CHECK SWITCH
DROP TANK FUELING
ON
OFF
PRIMARY
OFF
SECONDARY
OFF
SWITCH PANEL
PRESSURE FUELING AND DEFUELING ADAPTER VALVE
PRESSURE FUELING AND DEFUELING NOZZLE
GROUND WIRE
MANUAL FLOW AND NO-FLOW VALVE

AM.202

Figure 12-11.—Pressure fueling.

cases, the drop tanks and flight refueling package may also be refueled from this point.

The pressure fueling station on the aircraft is equipped with a pressure fueling and defueling receptacle and an electrical control panel. (See fig. 12-11.) The pressure fueling receptacle is standard on all aircraft which use the pressure fueling method. The electrical panel and controls differ from one aircraft to another, depending upon the complexity of the fuel system. The more complex systems may require several switches and lights. The General

Information and Servicing section of the applicable Maintenance Instructions Manual contains illustrations and instructions concerning the pressure fueling system.

The pressure nozzle shown in figure 12-11 is permanently attached to the refueler hose. The pressure nozzle is equipped with a ground wire which is used to drain off any static electricity that may have built up in the nozzle. However, once the nozzle is attached to the aircraft, it acts on its own ground.

As the connection is made, the pressure nozzle opens a spring-loaded valve within the inlet to the fuel tanks. Once the connection is made, there is no further need for grounding the other cells or tanks. Aircraft which employ the pressure fueling system are equipped with automatic equipment for shutting off the fuel flow when the tanks are full.

The following is a general procedure for pressure fueling an aircraft. Since the controls differ from one aircraft to another the applicable Maintenance Instructions Manual should always be checked prior to pressure fueling an aircraft.

1. Remove the pressure fueling receptacle safety cap by turning counterclockwise. Pull the pressure fueling nozzle dust cover up and to one side of the outer shell.

2. Ground the nozzle by inserting the grounding plug into its receptacle on the aircraft.

3. Lift the nozzle by its handles into position and engage the lower slot over the lower lug on the fueling receptacle. Tip the nozzle so that the upper slots engage the upper lugs. Press the nozzle in firmly so that all three nozzle lock keys are depressed. Lock the nozzle by rotating the lifting handles clockwise.

4. Set the refueling panel switches in the proper position and apply electrical power to the aircraft.

5. Position the vent monitors as necessary in accordance with the applicable Maintenance Instructions Manual. NOTE: The vent monitors are assigned to the various fuel system vents to insure that the aircraft's fuel cells are venting properly. Should the cells not vent properly, there is a possibility of rupturing the cell and even causing major structural damage.

6. With the nozzle locked in place, the opening handle is free to turn whenever fueling is to be started. To start fueling turn the handle to the FULL OPEN position. Rotating the opening handle more than 180 degrees opens the poppet valve in the nozzle and locks it in the OPEN position. Position the appropriate switch on the fuel panel to the FUEL position. The fuel should shut off automatically when the cells are full.

CAUTION: During pressure fueling the fuel system should be inspected carefully for leakage. If any leaks are apparent, fueling should be stopped and corrective action should be taken.

7. When fueling is complete, the pressure fueling nozzle is removed by rotating the lifting handles counterclockwise until the nozzle is unlocked from the fueling receptacle. The dust cover should be pulled up over the nozzle face immediately and the safety cap replaced on the aircraft receptacle.

Every safety precaution must be taken to insure that no dirt or foreign matter enters the nozzle and that the nozzle nose is completely clean before it is connected to the aircraft. The dust cover must be kept on the nozzle at all times except when actually fueling an aircraft.

The pressure fueling nozzle can be damaged by careless handling. Guard against dropping the nozzle or allowing it to swing heavily against structures or equipment during handling. Never drag the nozzle on the deck.

Never force the operating action of the nozzle. If the unit does not couple freely or open or close readily, locate and correct the misalignment or mechanical jam.

Defueling

Defueling may be necessary for a variety of reasons such as fuel cell repairs, removal of external fuel tanks, failure of fuel system components, and changing of fuel loads.

Aircraft which utilize pressure fueling are normally defueled from the pressure fueling adapter which allows the entire system to be defueled from a single point. Some older aircraft are equipped with one or more defueling valves. Some residual fuel will generally be left in the bottom of fuel cells following defueling. Residual fuel can usually be emptied or drained through the fuel cell water drain valves, using a special draining adapter and appropriate container to catch the fuel. When defueling external fuel tanks, it may be necessary to insert the defueler hose in the filler port.

Defueling will normally be accomplished outside the hangar and under controlled conditions as specified in the General Information and Servicing volume of the applicable Maintenance Instructions Manual. If it is absolutely necessary to defuel an aircraft in the hangar, doors should be open to provide ventilation through the hangar and all shop doors leading into the hangar should be closed. No work should be accomplished on or around the aircraft during the defueling operation and all sources of ignition should be prohibited in the area. The safety precautions defined in NavMat P 5100, the applicable MIM, and local directives should be strictly adhered to at all times.

OIL REPLENISHMENT

Identification of Aircraft Engine Oils

Aircraft engine oils are identified by their military specification number and/or 4-digit numbers; for example, 1065. The 4-digit numbering system identifies the intended use of the oil and its viscosity. The first digit designates the intended use, lxxx series being for aircraft engine lubrication. The last three digits indicate the viscosity; for example, 1065 oil has a viscosity rating of 65, 1080 oil has a viscosity rating of 80, etc. Viscosity is defined as the internal fluid resistance to flow caused by molecular attraction.

NOTE: Both the Navy and the Air Force use the Saybolt Scale for determining viscosity. Saybolt viscosity numbers should not be confused with SAE numbers.

The synthetic oils used in most turbojet engines are referred to by their military specification number; for example, MIL-L-23699.

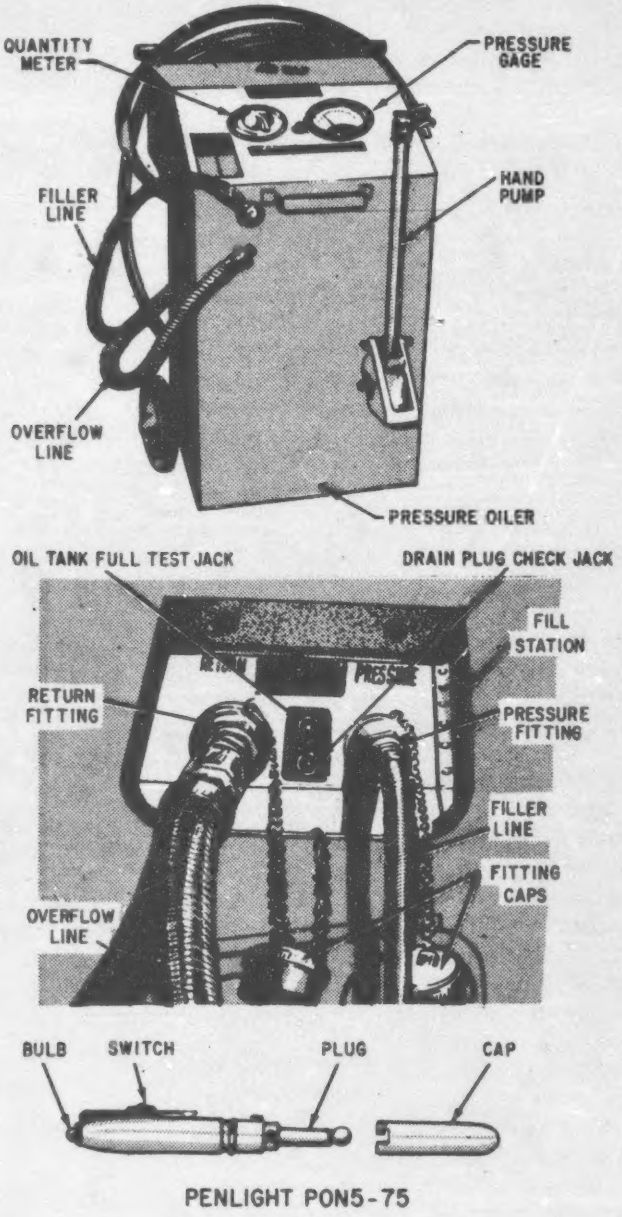
Servicing Engine Oil Tanks

Some aircraft engines utilize a combination dry and wet sump type of lubricating system while others are lubricated entirely with a dry sump type. Wet sump engines store the lubricating oil in the engine proper like automobile engines, while dry sump engines utilize an external tank mounted on or near the engine. Oil in jet engines serves the two-fold purpose of lubricating and cooling.

Servicing of the engine oil system is usually a simple task of checking the tank for the proper oil level and bringing the oil level up to the required amount. On aircraft with a dry sump system, servicing may consist of pumping uncontaminated oil directly into the supply tank. However, on some aircraft the tank is located in an inaccessible compartment, and a pressure tank is required to fill the oil tank.

Figure 12-12 provides an example of the pressure oiler, the engine oil pressure fill station located in the engine nacelle, and the penlight (PON5-75) used in servicing the engines on E-2A and C-2A aircraft. Servicing consists of the following steps:

1. Set the penlight switch to ON, with the cap in place. The bulb should light.
2. Remove the cap and insert the plug into the OIL TANK FULL test jack (at the fill station). The bulb should go on. If the bulb does not light, oil level is low and servicing is required.
3. Remove the penlight from the oil tank fill test jack and with the switch still ON insert into the DRAIN PLUG CHECK jack. If the bulb lights it is an indication of an accumulation of metallic material on either or both engine magnetic chip detectors. Call such indications to the attention of the appropriate supervisory personnel. If the bulb remains out proceed with servicing.
4. Reinsert the penlight into the OIL TANK FULL test jack.
5. Insure that the pressure oiler is properly filled. Prime the supply line, reset the quantity meter to zero, and connect the oiler filler line to the pressure fitting and the overflow line to the return fitting at the fill station.
6. Pump oil into the system until the penlight bulb lights and note the quantity on the quantity meter. If oil consumption exceeds limits, notify the appropriate maintenance chief.
7. If oil consumption is within limits, continue pumping oil at a slower rate until oil



AM.1211

Figure 12-12.–Oil System servicing equipment (E-2A/C-2A).

flow is observed at the overflow discharge in the pressure oiler.

NOTE: Checking and filling of the engine oil system of most jet engines must be accomplished within a specified time limit after engine shutdown. In most cases if the engine is not serviced within these time limits, the oil system must be drained and refilled to insure a proper quantity of oil or the aircraft could be turned up to scavenge oil from the engine gear case to the oil tank. In all cases follow the servicing instructions provided in the appropriate Maintenance Instructions Manual.

If unusually high oil consumption is noted, maintain an accurate record of consumption as specified by the applicable inspection requirements or the MIM. Oil consumption can be a reliable indicator of impending engine malfunction and a determining factor in deciding whether an engine is acceptable for flight status.

CAUTION: Do not overfill engine oil systems. The system previously discussed requires filling to overflow, however, some aircraft oil systems require that adequate space be allowed for normal foaming of the oil and expansion when the engine is operating.

Servicing Constant Speed Drive Assemblies

Several late model reciprocating and jet engine aircraft utilize a constant speed drive (CSD) assembly to maintain the aircraft's generator(s) at a constant speed. The assembly transfers and converts variable speed rotation of the aircraft engine into a constant speed rotation necessary to drive the generator at a constant speed which will meet all the aircraft's electrical demands.

At least one aircraft features a combination constant speed drive/starter (CSD/S) which provides both pneumatic starting for the engines and constant speed drive for the generator. This CSD/S can be operated in engine starter, constant speed drive, or air turbine motor modes of operation.

Proper operation of any CSD assembly is extremely dependent on proper servicing by personnel assigned to line maintenance. In most cases the CSD or CSD/S must be serviced within a specified period after engine shutdown to obtain an accurate oil level reading. If this time is exceeded the oil reservoir must be drained prior to servicing with the required volume of specified lubricating oil or the aircraft turned up so that the oil level can be checked within the designated time limit.

Several types of lubricating oils are utilized in the various types of CSD assemblies found in naval aircraft. Use only the specified oil indicated in the General Information and Servicing volume of the MIM for the particular aircraft being serviced. Improper lubrication can cause internal damage and disastrous failure. To allow for normal expansion and some foaming of the oil under use, do not overfill the oil tank.

NOTE: The synthetic oil used in some aircraft engines and CSD assemblies is harmful to human skin and respiratory tract, and has a deteriorating effect on rubber and painted surfaces. Handle in such a manner as to prevent skin contact and/or damage to the aircraft finishes.

The presence of contamination in the lubricating system of aircraft engines and CSD units can be as disastrous to their operation as the presence of contamination in oxygen, hydraulic, and fuel systems. Proper handling of lubricants and servicing equipment and strict conformance to servicing instructions provided in the MIM will minimize the possibility of introducing external contamination. Any suspected contamination should be immediately called to the attention of the appropriate maintenance supervisor.

HYDRAULIC FLUID REPLENISHMENT

Identification of Hydraulic Fluid

Aircraft hydraulic fluids are identified by their military specification number. Hydraulic fluid, MIL-H-5606C, is now being used in the hydraulic systems of all naval aircraft. This fluid is also used in the shock struts, shimmy dampers, and brake systems of all aircraft. MIL-H-5606C hydraulic fluid is colored red and is available in 1-quart, 1-gallon, 5-gallon, and 55-gallon containers.

NOTE: Hydraulic fluid MIL-H-6083C is a preservative type hydraulic fluid used in the preservation of hydraulic systems and components. While it is red in color and generally considered compatible with MIL-H-5606C hydraulic fluid, it should NOT be used to service aircraft hydraulic systems.

Servicing Hydraulic Systems

Older type aircraft hydraulic systems are serviced by checking the fluid level (on a sight gage which is usually located on the side of the reservoir) and filling to the prescribed level. Before adding fluid to this type reservoir, always check the reservoir instruction plate for proper filling instructions. The instructions plate will be attached either to the reservoir or to the aircraft structure near the filler opening of the reservoir. The instruction plate contains the following information:

Total capacity of the system.
Reservoir capacity.
Refill level.
Specification and Color of fluid.
Correct position of all actuating cylinders during filling.

Any other information considered necessary during the filling of the reservoir.

NOTE: After opening a can of hydraulic fluid, the entire contents should be poured into the fill stand or servicing unit immediately. This will eliminate the possibility of the fluid absorbing dust and grit from the air. Current instructions require that any remaining fluid left in the hydraulic fluid container, after servicing a fill stand/servicing unit, be discarded and that the empty fluid container be destroyed immediately and not used to store or handle any other fluid.

Hydraulic systems can only be serviced with approved 3-micron absolute filtered dispensers. Figure 12-13 shows a fill stand used to service some aircraft hydraulic systems. The fill stand is connected to the aircraft hydraulic system at a quick disconnect which is provided for reservoir filling. The fill stand can be operated with air pressure or using the handpump. Some aircraft systems provide for filling several reservoirs from a single point while others have provisions for filling each reservoir individually.

Another type of hydraulic servicing unit, shown in views A and B of figure 12-14, is a portable hand-operated unit designed to accept the standard 1-gallon can of hydraulic fluid and to dispense it contamination free to aircraft hydraulic reservoirs. This is done by pumping the hydraulic fluid from the original container, which functions as the unit's reservoir, directly into the aircraft's reservoir without exposing the fluid to open air or other atmospheric contamination. In addition, waste of hydraulic fluid is reduced since a partially used can of fluid does not have to be thrown away but can be retained in its contamination-free condition, in the unit, until it is needed and used on another job.

This type of servicing unit comes unpainted and is to remain as such to eliminate the possibility of paint chips getting into the aircraft hydraulic system and contaminating them. All exposed parts of the unit have either been plated or are of hard anodized aluminum. The unit is also constructed so that it can stand on a 15-degree slope without turning or sliding and has a neoprene strip on its base to prevent scratching or marring any surface on which it rests.

In addition, this unit provides exceedingly fine filtration through the use of 3-micron filters which remove minute particles that may be in the fluid. With the use of this unit, the can of fluid is sealed into the unit, and the fundamental feature of preventing contamination from exposing the fluid to the atmosphere and other external contamination is accomplished.

Most of the newer type aircraft have a visible means (usually sight gages) for checking fluid level; however, some are equipped with lights which indicate fluid level.

Information concerning servicing of the hydraulic reservoirs of a particular type aircraft is contained in the General Information and Servicing volume of the applicable Maintenance Instructions Manual.

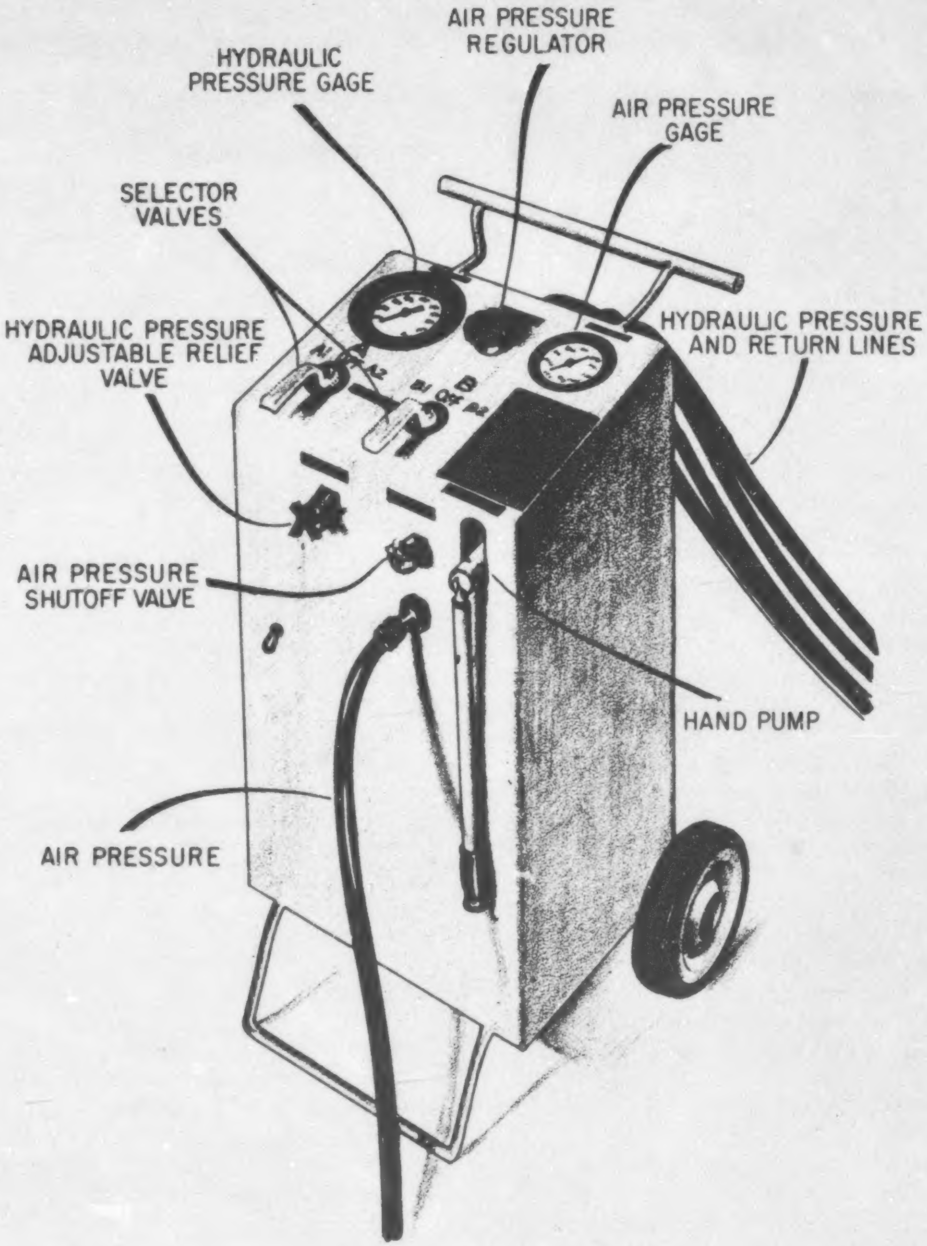
PNEUMATIC SERVICING

Landing gear struts, hydraulic accumulators, and various air storage bottles throughout most naval aircraft must be serviced with compressed air of nitrogen.

Pneumatic Servicing Equipment

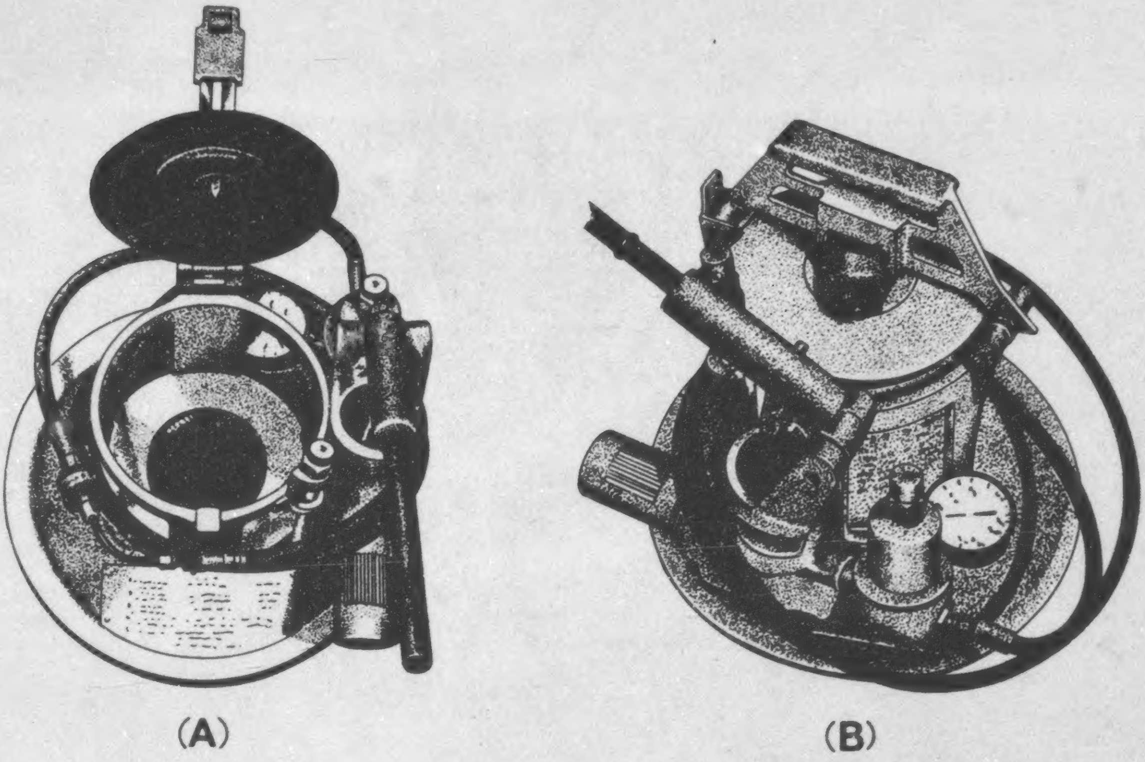
The three main types of pneumatic servicing equipment are the portable air bottle, the nitrogen/air or nitrogen servicing trailer, and the portable, high-pressure air compressor.

PORTABLE NITROGEN/AIR BOTTLES.– The portable nitrogen/air bottle is a



AM.204

Figure 12-13.—Hydraulic fill stand.



AM.902

Figure 12-14.–Loe Hydraulic Servicing Unit, Model H250-1.

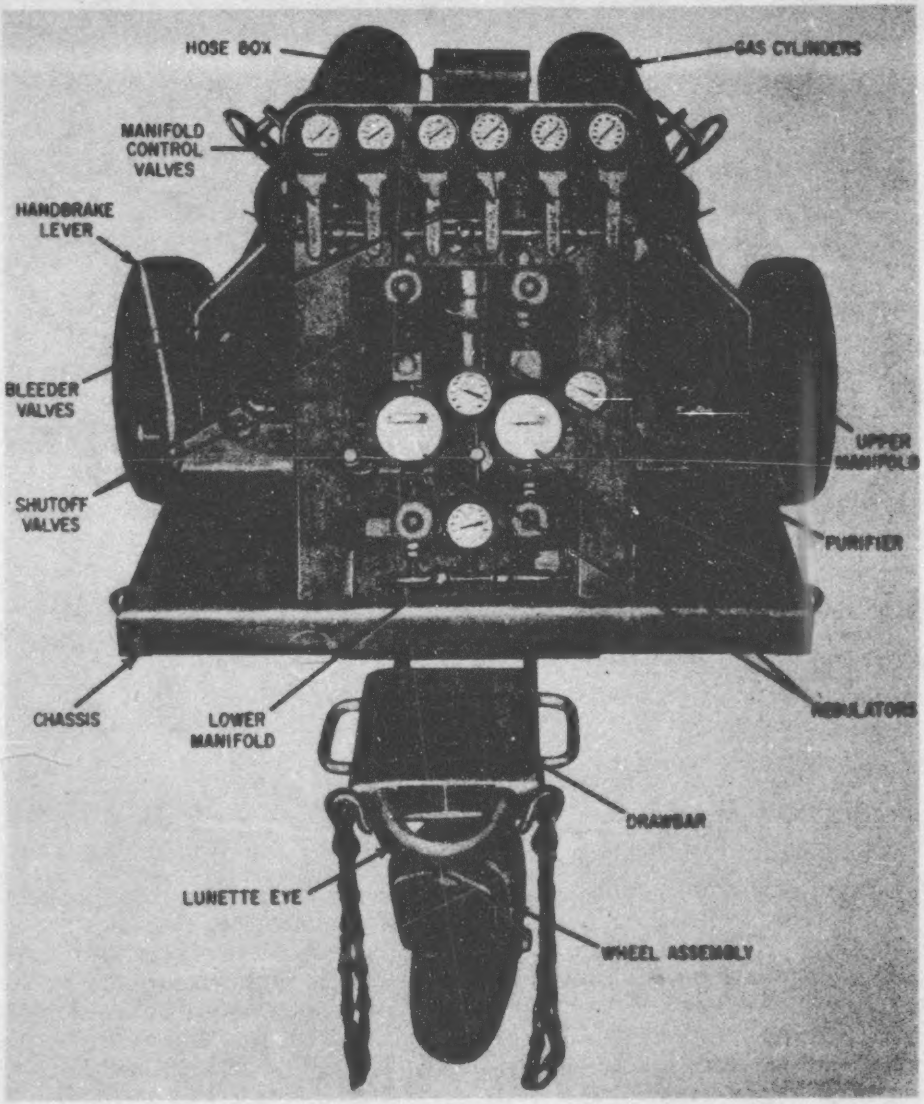
small high-pressure cylinder in a tubular steel frame. It has a pressure regulator and two gages. One gage indicates cylinder pressure and the other indicates regulated pressure. A valve mounted on the cylinder allows the user to shut the nitrogen/air off when the bottle is not in use.

Each portable nitrogen/air bottle has recharge and servicing instructions printed on a plate which is attached to the frame. Only dry filtered air or nitrogen should be used in recharging a nitrogen/air bottle which is to be used in servicing aircraft components. When recharging a portable nitrogen/air bottle, care should be taken to insure that the cylinder pressure does not exceed that listed in the instructions.

AIR OR NITROGEN SERVICING TRAILER.–A servicing trailer similar to the one shown in figure 12-15 will be found at most naval air activities for servicing aircraft hydraulic and pneumatic systems. This trailer is designed to carry six air or nitrogen storage cylinders and the necessary flow controlling mechanism. It has a 30-foot hose which is stowed in a box mounted between the top two bottles.

The air or nitrogen servicing trailer has a purifier (dehydrator) assembly. This purifier assembly is essentially a reservoir which contains a chemical drying agent. This chemical drier is provided to remove any moisture which may have adhered to the valves or have been accidentally introduced into the system. The chemical is contained in a metal cartridge or can which is changed periodically. The gas passes through the drier just before it enters the servicing hose.

The bottles on the air or nitrogen servicing



AM.207

Figure 12-15.—Air or nitrogen servicing trailer.

trailer may be recharged using a high-pressure compressor.

NOTE: When recharging the cylinders on the air or nitorgen servicing trailer, insure that the cylinder pressure does not exceed the pressure specified for the equipment being recharged.

When operating the servicing trailer, the following precautions for safe operation should be observed.

Only a qualified operator should operate the trailer while charging a system or component. Complete familiarity with the trailer is a basic prerequisite to safe operating techniques.

The servicing hose end and installation connection fitting should be thoroughly inspected prior to servicing and any particles of foreign material removed.

Never charge a system or component without the proper fusible safety plug and blowout disc in the trailer charging system.

Always know the pressure existing in the system to be filled and the pressures in all the cylinders to be used up in the cascading process before commencing charging operation.

A malfunctioning pressure regulator should be disconnected from the line by closing its associated shutoff valve. The trailer can then be operated with the remaining regulator.

The charging hose must never be tightly stretched to reach a connection. Position the trailer so that the hose is not under tension while servicing an aircraft.

After servicing an aircraft system, the servicing hose should be stowed in its container to insure that it is not damaged by dragging along behind the trailer.

AIR COMPRESSORS.–There are many models of compressors in use throughout the Navy. Such a variety makes it difficult, at best for the average man to be master of all. The situation is further complicated by the variety of configurations of dials and gages, regulator controls, hoses, and hose fittings on the same model compressor.

Most air compressors have an instructions plate mounted on the control panel to aid in proper operation. These instructions plates should be kept in good condition, that is, they should not be painted over or scratched and marred. If the instructions plate is not available on the compressor, the Operation and Service Instructions Manual for the particular air compressor will contain all the necessary instructions for the operation and maintenance of the compressor.

Most of the newer high-pressure type air compressors will supply air pressure from 0 to 5,000 psi. Handling of compressed air at pressures up to 5,000 psi requires extreme caution. The following servicing instructions will help to insure a safe job:

1. Always use a remote control pressure gage that is not defective and is properly calibrated.

NOTE: In accordance with current instructions, all gages used in servicing aircraft hydraulic and pneumatic systems must be calibrated periodically to insure their accuracy.

2. Never use an uncontrollable source of high-pressure air. Always use a regulator in the air system.

3. Always open the control valves slowly. Inflate the component slowly–10 psi increments–until the recommended pressures are reached.

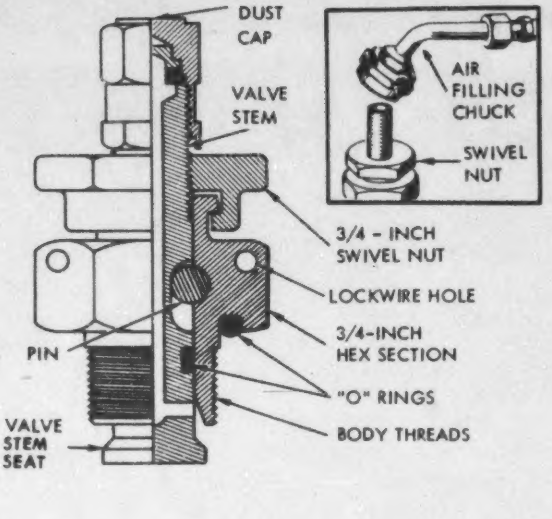
High-pressure air compressors like the air or nitrogen servicing trailer are equipped with one or more dehydrators. The cartridges used in these dehydrators must be replaced periodically, depending upon the weather conditions. In damp, humid weather it will be necessary to replace the dehydrator cartridges more often then in dry, arid weather.

Servicing Landing Gear Struts

For efficient operation of shock struts, the proper fluid level and air or nitrogen pressure must be maintained. In order to check the fluid level, the shock strut must be deflated and in the fully compressed position. Deflating a strut can be a dangerous operation unless servicing personnel are thoroughly familiar with the high-pressure air valve and observe all the necessary safety precautions.

The high-pressure air valve shown in figure 12-16 is used on all naval aircraft. This air valve (referred to by its MS number, MS 28889-1) is used on struts, accumulators, and various other components which must be serviced with high-pressure air or nitrogen. The MS 28889-1 high-pressure air valve has no valve core. Turning the 3/4-inch swivel nut clockwise draws the valve stem seat up into the valve body, thereby forming a metallic seal which traps the high-pressure air or nitrogen in the component.

The following is a complete procedure for deflating a typical shock strut, servicing with hydraulic fluid, and reinflating.



AM.208

Figure 12-16.—High-pressure air valve, type MS 28889.

1. Position the aircraft so that the shock struts are in the normal ground operating position. Make certain that personnel, workstands, and other obstacles are clear of the aircraft.

NOTE: Some aircraft must be placed on jacks for servicing the shock struts.

2. Remove the dust cap from the air valve.

3. Release the air pressure in the strut by slowly turning the swivel nut counterclockwise.

CAUTION: When loosening the swivel nut, make sure the 3/4-inch hex body is either lockwired in place or held tight with a wrench. If it is loosened before the air pressure has been released, serious injury may result.

4. Make sure that the shock strut compresses as the air pressure is released. In some cases it may be necessary to rock the aircraft after deflating to insure complete compressing of the strut.

5. When the strut is fully compressed, the valve assembly may be removed by cutting the safety wire and turning the 3/4-inch hex body nut counterclockwise.

6. Fill the strut to the level of the air valve opening, using the type hydraulic fluid specified on the shock strut instruction plate. Figure 12-17 illustrates the instruction plate found on one type aircraft main landing gear strut. NOTE: The instruction plate may be found on the strut or on the wheel door near the strut.

7. Reinstall the air valve assembly, using a new O-ring packing. The recommended torque is 100 to 110 inch-pounds.

8. Lockwire the air valve assembly to the strut, using the holes provided in the hex body nut.

9. Inflate the strut, using a regulated high-pressure source of dry air or nitrogen. CAUTION: Under no circumstance should any type of bottle gas other than compressed air or nitrogen be used to inflate shock struts.

NOTE: On some shock struts the correct amount of inflation is determined by measuring the amount of extension (in inches) between two given points on the strut and comparing this figure with the amount of air in the strut. (See fig. 12-17.) The proper procedure will always be found on the instruction plate (fig. 12-17). If the instructions on the instruction plate are not legible, reference should always be made to the General Information and Servicing section of the applicable Maintenance Instructions Manual. Shock struts should always be inflated slowly to avoid excessive heating and overinflation.

10. Tighten the swivel hex nut. Recommended torque is 50 to 70 inch-pounds.

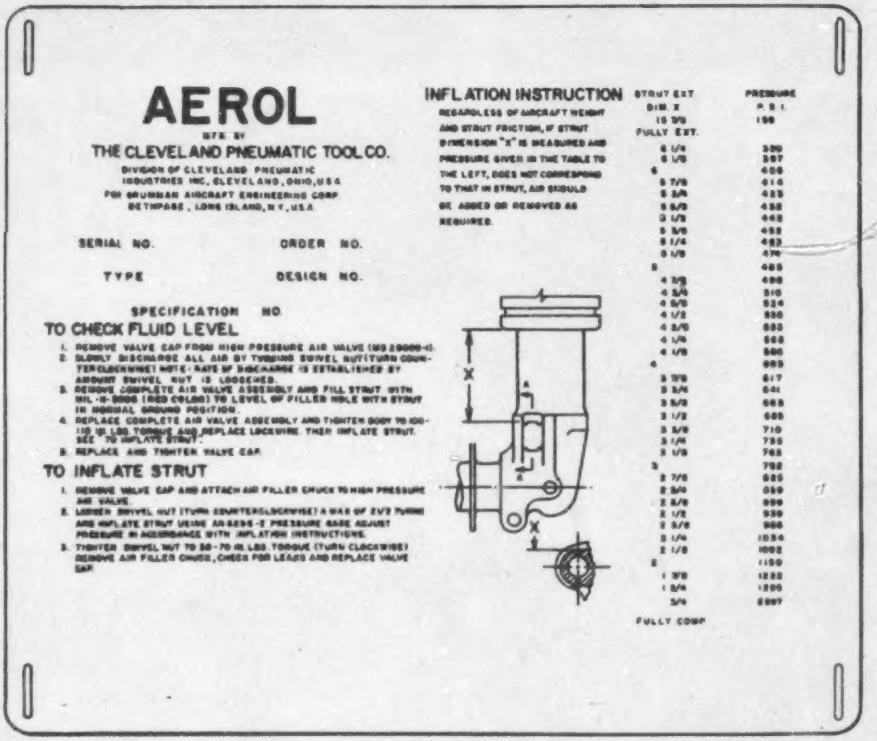
11. Remove the high-pressure air line chuck and install the valve cap. Tighten the valve cap fingertight.

CAUTION: Do not remove the high-pressure air line chuck before securing the swivel nut.

Since some aircraft struts require special servicing procedures, the General Information and Servicing section of the applicable Maintenance Instructions Manual should always be checked prior to servicing the shock struts of any aircraft.

Servicing Air Storage Bottles

Some aircraft use nitrogen/air storage bottles for the various emergency operations which are necessary for the safe operation of the aircraft and the safety of the crew. Air storage bottles are used for such functions as emergency brakes,



AEROL

THE CLEVELAND PNEUMATIC TOOL CO.

DIVISION OF CLEVELAND PNEUMATIC INDUSTRIES INC, CLEVELAND, OHIO, U.S.A.

FOR GRUMMAN AIRCRAFT ENGINEERING CORP BETHPAGE, LONG ISLAND, N.Y., U.S.A.

SERIAL NO.

ORDER NO.

TYPE

DESIGN NO.

SPECIFICATION NO.

TO CHECK FLUID LEVEL

TO INFLATE STRUT

INFLATION INSTRUCTION

REGARDLESS OF AIRCRAFT WEIGHT AND STRUT FRICTION, IF STRUT DIMENSION "X" IS MEASURED AND PRESSURE GIVEN IN THE TABLE TO THE LEFT, DOES NOT CORRESPOND TO THAT IN STRUT, AIR SHOULD BE ADDED OR REMOVED AS REQUIRED.

AM.209

Figure 12-17.–Landing gear strut servicing instruction plate.

emergency landing gear extension, and emergency canopy operation.

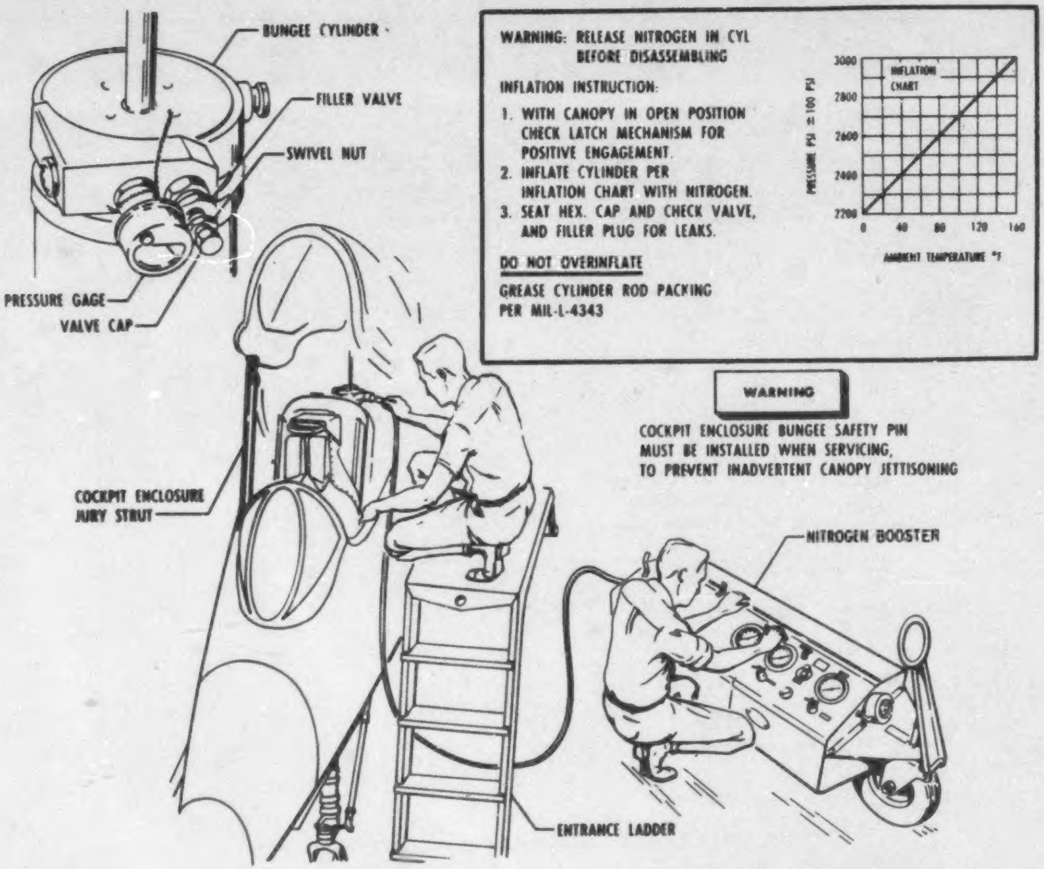
Some aircraft have a pneumatic system which will maintain the required pressure in these bottles in flight. However, most of these pneumatic systems require servicing on the ground with an external source of high-pressure air or nitrogen prior to each flight.

The canopy bungee cylinder on the A-4E aircraft is an example of a storage unit which requires pneumatic servicing. This unit aids in opening and closing the canopy and in emergencies removes the canopy from the aircraft. The Maintenance Instructions Manual specifies the use of high-pressure nitrogen in this unit; therefore, the nitrogen booster is used in servicing (See fig. 12-18.)

The nitrogen booster shown in figure 12-18 has one 1,800 psi bottle of nitrogen enclosed behind the control panel and utilizes a source of low-pressure air to operate the booster or pump which is used to boost the nitrogen to the required pressure.

Since gases expand with heat and contract when cooled, air storage bottles are usually filled to a given pressure at ambient temperature. A graph similar to that shown in figure 12-18 is usually mounted on a plate or decal on or near the bottle or air filler valve. If the instructions plate is missing or not readable the information may be found in the General Information and Servicing section of the applicable Maintenance Instructions Manual.

Pressure should be added to air storage bottles slowly in order not to build up heat from rapid transfer. Care should be taken to insure that air storage bottles are not overinflated.



WARNING: RELEASE NITROGEN IN CYL
BEFORE DISASSEMBLING

INFLATION INSTRUCTION:

1. WITH CANOPY IN OPEN POSITION CHECK LATCH MECHANISM FOR POSITIVE ENGAGEMENT.
2. INFLATE CYLINDER PER INFLATION CHART WITH NITROGEN.
3. SEAT HEX. CAP AND CHECK VALVE, AND FILLER PLUG FOR LEAKS.

DO NOT OVERINFLATE

GREASE CYLINDER ROD PACKING
PER MIL-L-4343

WARNING

COCKPIT ENCLOSURE BUNGEE SAFETY PIN MUST BE INSTALLED WHEN SERVICING, TO PREVENT INADVERTENT CANOPY JETTISONING

AM.211

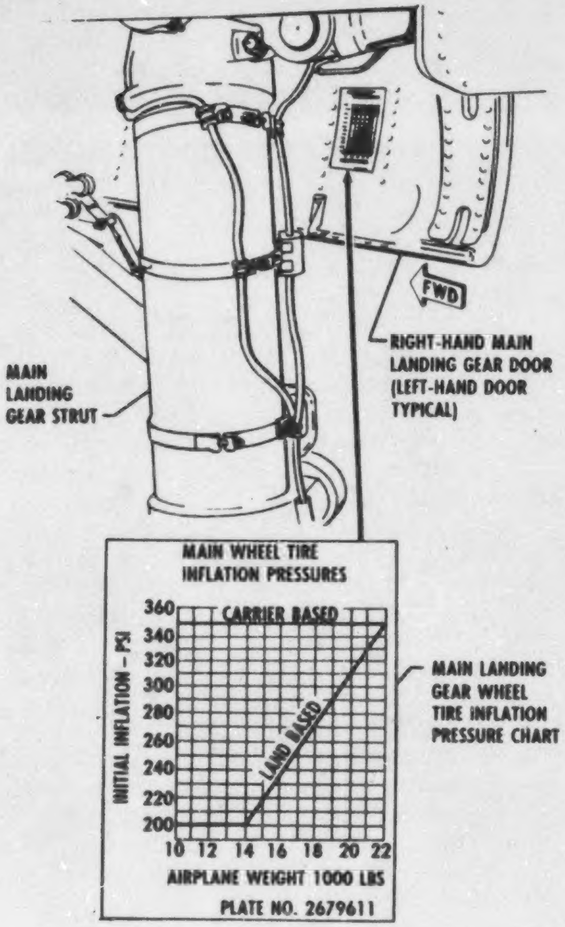
Figure 12-18.—Servicing the A-4E canopy bungee system.

Inflation of Tires.

Correct air pressure must be maintained to receive satisfactory service from aircraft tires. Air pressure must be checked daily with an accurate gage. Tires must be inflated to the pressures specified for the type of operation (ashore or afloat) and the gross weight of the particular type aircraft. Tire inflation data is usually found as illustrated in figure 12-19. In case the plate is missing from the aircraft, this data may also be found in the General Information and Servicing section of the applicable Maintenance Instructions Manual.

Overinflation reduces the contact area of the tire, causing it to wear faster at the tread center. Failure due to carcass ruptures and breaks in the tire cords which result from contacts with foreign objects are usually caused by overinflation.

Underinflation increases contact area and causes the tire to wear rapidly and unevenly at



AM.212

Figure 12-19.—Tire inflation chart.

the outer edges of the tread. An underinflated tire flexes excessively and develops high temperatures which weaken the tire cords. An underinflated tire may also slip on the wheel when landing and shear off the valve stem.

To determine the proper inflation pressure, check the inflation chart. For example, using the chart in figure 12-19, if the gross weight of the aircraft is 20,000 pounds, the correct tire pressure for that aircraft when shore based would be 310 psi. When carrier based, the pressure would be maintained at 350 psi regardless of the gross weight.

If the tire pressure is found to be low, air should be added from a regulated source. CAUTION: An unregulated high-pressure air source for tire inflation is a hazard. Tire inflation source pressure should be carefully monitored. If high-pressure cylinders such as the portable air bottle or the air or nitrogen servicing trailer are used, the regulator must be used to prevent inadvertent overinflation.

A remote inflator unit should always be used when inflating tires. The operator of this unit should always stand at right angles to the landing gear axle, directly in front or in the rear of the tire. The operator should also stand at the full length of the inflator unit hose. This will prevent the operator from being struck by pieces of the wheel in case of failure.

CAUTION: When an aircraft wheel is to be removed from the aircraft, the air must be removed prior to removing the wheel. This precaution must be taken because of the possibility that the bolts in split type wheels might have been sheared from landing, thus causing the wheel halves to separate when the axle nut is removed. In the past, several people have been killed by their failure to remove the air from the tire before removing the axle nut.

AIRCRAFT LUBRICANTS AND LUBRICATION

The proper lubrication of modern high-speed, high-altitude aircraft is an extremely important part of line maintenance. All maintenance personnel should be familiar with the various types of lubricants, their specific use, and the method and frequency of application.

LUBRICANTS

Lubricants are substances which are spread in a thin coat or film over surfaces which move across each other to reduce friction and wear between the surfaces. Lubricants also help to dissipate heat generated in bearings, prevent corrosive attack on bearing surfaces, and protect the bearings from foreign particle contamination. If adequate lubrication is not provided as specified in the various inspection requirements and Maintenance Requirements Manuals, bearing failure, binding of mechanisms, etc., can be expected.

Lubricants are classified as greases, oils, or dry film lubricants. Greases and oils are the two most common lubricants; however, certain dry film lubricants are in limited use and others are being evaluated.

Greases used in roller element type bearings generally consist of an intimate dispersion of a thickening agent with oil. The oil can be a petroleum derivative (mineral) or chemical synthesis (synthetic) depending on the expected temperatures encountered in its application. The thickener keeps the oil in suspension and acts as a reservoir. As the moving parts come in contact with the grease, oil adheres to the bearing surfaces. Bleeding of the oil from the grease takes place gradually so that a small quantity of oil sufficient for proper operation is continuously supplied. The oil that is picked up by the moving parts of the bearing gradually deteriorates from the effects of oxidation, is lost by evaporation, or is thrown free by centrifugal force. As this process continues, the oil content of the grease is depleted and the lubricant will no longer give adequate service. It is for this reason that during lubrication all the old lubricant should be forced from each lubrication point until new lubricant appears.

Types of Lubricants

It is impractical to cover each type of lubricant approved by NavAirSysCom and in use at the present time. The types of lubricants recommended for various aircraft applications will vary with each type of aircraft to some degree depending on the aircraft manufacturer. Some of the more common types are discussed in the following paragraphs.

AIRCRAFT GENERAL PURPOSE GREASE, WIDE TEMPERATURE RANGE.–MIL-G-81322 is used in the lubrication of aircraft accessories operating at high speeds over a wide temperature range (–65° to +350°F). It was specifically designed for use in aircraft wheel bearings, anti-friction bearings, gear boxes, and plain bearing applications that fall within the operating temperature range. It is available in 1-pound cans, 35-pound pails, and 14-ounce cartridges.

NOTE: MIL-G-81322 grease is not compatible with other lubricants. If it is to be used as a recommended substitute for another type of grease, insure that all traces of the original grease are removed first.

AIRCRAFT GENERAL PURPOSE GREASE.–MIL-G-7711 is designated for use in gear boxes, anti-friction bearings, and plain bearings where operation at both low and high temperatures (–40° to +250°F) may be required.

AIRCRAFT AND INSTRUMENT GREASE, GEAR AND ACTUATOR SCREW.–MIL-G-23827 is intended for use in ball, roller, and needle bearings; sliding and rolling surfaces of instruments, cameras, electronic gear, and aircraft control surfaces; aircraft gears, actuator screw mechanisms, and other equipment requiring a lubricant with a high load carrying capacity over a temperature range between -100° to +250°F. It can withstand temperatures up to 300°F for short periods of time.

NOTE: MIL-G-23827 supersedes MIL-G-3278, 7118, and 7421, which are still listed in many Maintenance Instructions Manuals as of this writing. MIL-G-23827 grease should not be used in contact with rubber and painted or acrylic surfaces as it will damage these surfaces. Bearings should be clean and free of other greases, oil, and water before application. While this is true in lubricating all bearings it is especially important when applying MIL-G-23827 grease.

PNEUMATIC SYSTEM GREASE.–MIL-G-4343B is intended for use as a lubricant between rubber and metal parts of pneumatic systems. It is also used on pressurized cabin bulkhead grommets and other mechanisms where rubber-to-metal lubrication is required.

MOLYBDENUM DISULFIDE GREASE.–MIL-G-21164C is intended for use as a lubricant for accessory splines, heavy loaded sliding surfaces, and for antifriction bearings carrying high loads and operating through wide temperature ranges. The molybdenum disulfide affords better than average reliability in preventing or delaying seizure in the event of marginal or inadequate lubrication.

AIRCRAFT BALL AND ROLLER BEARING GREASE.–MIL-G-25013D is intended for use in antifriction bearings exposed to low torque at temperatures as low as −100°F and will provide adequate lubrication for extended periods at temperatures as high as +450°F.

NOTE: MIL-G-25013D supersedes MIL-G-27343A which may appear in some Maintenance Instructions Manuals and (03) Overhaul Manuals.

GENERAL PURPOSE GREASE.–MIL-G-23549A is a molybdenum disulfide grease intended for general purpose use on automotive and ground support equipment that could be exposed to high-pressure steam, salt water, high load, and high temperatures and low speed. It is not generally designed for aircraft use.

NOTE: In all cases utilize the type of lubricant designated in the General Information and Servicing volume of the applicable Maintenance Instructions Manual and the applicable Maintenance Requirements Cards.

GENERAL PURPOSE LUBRICATING OILS.–Oil procured under Specification MIL-L-7870, is used primarily for general squirt can lubrication. It is used on canopy tracks, aileron and trim tab hinges, and many other locations on the aircraft where a light, low-temperature, corrosion-preventive lubricant is required.

Federal Specification VV-L-800 is a preservative type lubricating oil which contains corrosion and oxidation inhibitors and water-displacing agents. This type lubricating oil is specified for use on most aircraft as a lubricant for all piano hinges.

METHODS OF APPLICATION

The different types of lubricants can be applied by any one of the following methods, as applicable.

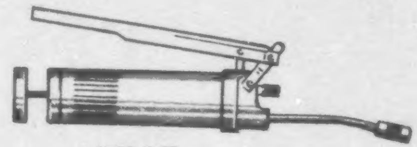
Grease Guns

Grease guns are used for general heavy-duty lubrication. There are numerous types and sizes of grease guns available for different purposes. The hand-operated type guns are the most common; however, pressure-operated types are also available.

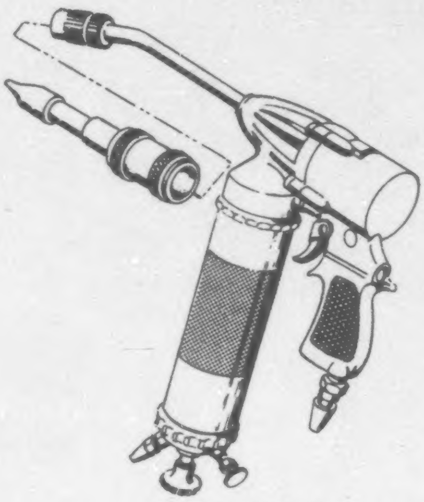
Grease guns are used in conjunction with "zerk" fittings for lubrication of landing gear actuators and other similar components. The operation of the zerk fitting is similar to the one-way check vlaves found in hydraulic systems. When the grease gun is removed, a spring-loaded ball check is seated, preventing the grease in the unit from escaping back through fitting.

A special flush type grease fitting is now being used on many installations to replace the old zerk type fitting. They are press fitted into the unit and require a special lubrication adapter, which can be attached to the grease gun.

Figure 12-20 illustrates both types of guns with the adapter. The grease guns may be



LEVER TYPE



PRESSURE TYPE

AM.213

Figure 12-20.–Grease guns.

equipped with a flexible hose instead of the rigid extensions as shown in figure 12-20.

Oil or Squirt Can

Oil or squirt cans are used for general lubrication, using the specified oils for the component or part being lubricated. Always check to make sure the squirt can contains the proper lubricant before using it.

Hand

This method of lubrication is generally employed for packing wheel bearings.

Brush

This method of lubrication is employed when it is necessary to cover a large area with a lubricant or for coating tracks and guides.

LUBRICATION CHARTS

The lubrication requirements for each model of aircraft are given in the General Information and Servicing section of the Maintenance instructions Manual. These instructions appear in the form of tables and charts.

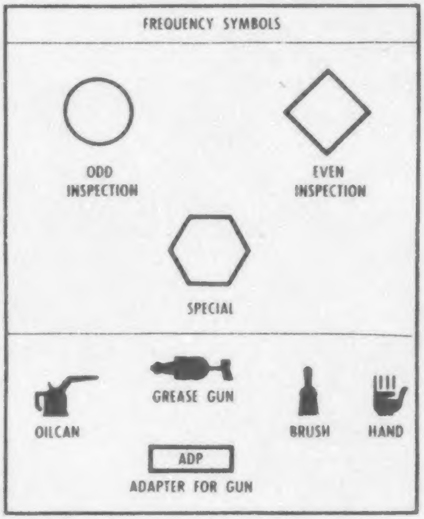
A table of lubricants similar to the one illustrated in figure 12-21 lists all of the various types of lubricants to be used in lubricating the entire aircraft. Additional information, such as frequency symbols, application symbols, specification numbers and symbols, and the NATO symbol, is provided on this table.

The lubrication of most new type aircraft is performed using the applicable Maintenance Requirements Card as a guide. Lubrication is required at the intervals specified on the various Maintenance Requirement Card sets (Preflight, Daily, Postflight, Special (7 day, 14 day, etc.), Conditional, and Calendar). Figure 12-22 illustrates the front and back of one of these cards which covers the lubrication of the A-4E aircraft. The card shows the types of lubricants required, number of lubrication points, an illustration of the unit to be lubricated, and the method of application.

NOTE: The frequency symbols used in figure 12-21 are not necessarily standard for all aircraft. In reading the lubrication chart for a

TABLE OF LUBRICANTS

MILITARY SYMBOL	NATO SYMBOL	NOMENCLATURE	SPECIFICATION NUMBER
NONE		ANTISEIZE COMPOUND, FEL-PRO C-5 FELT PRODUCTS CO., CHICAGO, ILL.	
CT		CORROSION PREVENTIVE COMPOUND, SOLVENT CUTBACK, COLD APPLICATION	MIL-C-16173, GRADE 3 AND 4
BRW		GREASE, AIRCRAFT, BALL AND ROLLER BEARING, WIDE TEMPERATURE RANGE	MIL-G-81322A
GIA	G 354	GREASE, AIRCRAFT AND INSTRUMENT GEAR AND ACTUATOR SCREW	MIL-G-23827
GGA	G-355	GREASE, GRAPHITE, AIRCRAFT LUBRICATING	MIL-G-7187
GMD		GREASE, MOLYBDENUM DISULFIDE	MIL-G-21164
OHC	C-635	HYDRAULIC FLUID, PETROLEUM BASE, PRESERVATIVE	MIL-H-6083
GPS		LUBRICATING GREASE, PNEUMATIC SYSTEM	MIL-G-4343
OGR		LUBRICATING OIL, GEAR, PETROLEUM BASE	MIL-L-6086
OGP	0-142	LUBRICATING OIL, GENERAL PURPOSE LOW TEMPERATURE	MIL-L-7870
PL-SPECIAL		LUBRICATING OIL, GENERAL PURPOSE, PRESERVATIVE	VV-L-800
NONE		MOLYBDENUM DISULFIDE POWDER, LUBRICANT	MIL-M-7866



AM.214

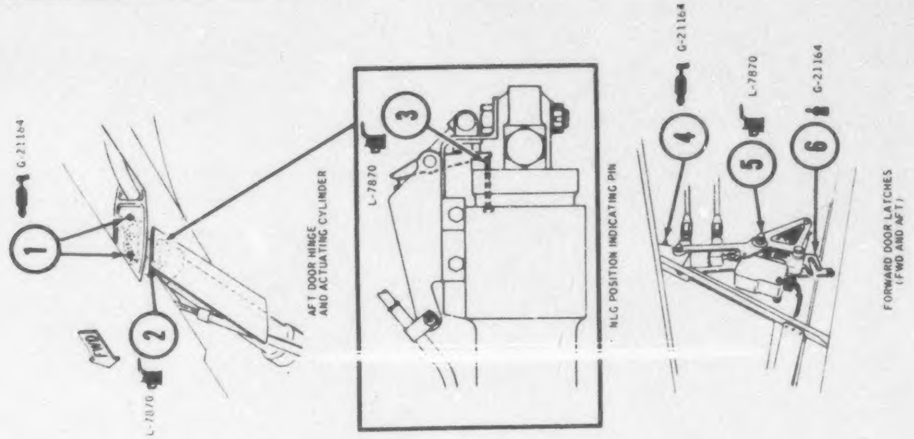
Figure 12-21.—Table of lubricants for an aircraft.

TASK MIN	WORK AREA	CARD	PUBLICATION NUMBER	CHANGED	ELEC PWR OFF HYD PWR OFF
		49.4	NAVAIR 01-40AVC-6-4		
5.0	2	3. Lubricate Forward and Aft Nose Landing Gear Doors as Follows:			

ITEM	NOMENCLATURE	NO. OF POINTS	SPECIFICATION
1.	Nose Landing Gear Actuating Cylinder Upper Fitting	2	MIL-G-21164
2.	Nose Gear Aft Door Hinge	1	MIL-L-7870
3.	Nose Landing Gear Position Indicating Pin	1	MIL-L-7870
4.	Forward Door (fore and aft) Latch Mechanism Actuating Cylinders	2	MIL-G-21164
5.	Forward Door (fore and aft) Latch Moving Parts (except sealed bearings)	2	MIL-L-7870
6.	Forward Door (fore and aft) Latch Hooks	2	MIL-G-21164

(A)

CARD	PUBLICATION NUMBER	FORWARD AND AFT NLG DOORS LUBRICATION	CHANGED
49.5	NAVAIR 01-40AVC-6-4		


G-21164
1
2
FWD
L-7870
AFT DOOR HINGE AND ACTUATING CYLINDER
L-7870
3
NLG POSITION INDICATING PIN
G-21164
4
L-7870
5
G-21164
6
FORWARD DOOR LATCHES (FWD AND AFT)

(B)

AM.215

Figure 12-22.—Maintenance Requirements Card for lubricating an aircraft. (A) Front; (B) back.

particular aircraft, always refer to the applicable table of lubricants for the correct interpretation of all symbols.

GENERAL LUBRICATION PROCEDURES

Prior to lubricating any components or parts, all foreign matter should be removed from joints, fittings, and bearing surfaces. A clean soft cloth saturated with a cleaning solvent can be used for this purpose. The lubricant should be applied sparingly to prevent accumulation of dust, dirt, and other foreign matter.

When applying lubricants through pressure type fittings with a grease gun, make sure the lubricant has emerged around the bushing. If no grease appears around the bushing, check the fitting and grease gun for proper operation. Always make sure the grease gun is properly attached to the fitting and wipe up all excess grease when finished. If the new flush type fitting is being used, the grease gun must be equipped with the flush type adapter, and it must be held perpendicular to the surface of the fitting when greasing, if possible.

NOTE: Some of the high-speed mechanisms on modern aircraft are critical as to the lubricant required. If the exact lubricant specified in the Maintenance Instructions Manual cannot be obtained, and there is no substitute listed, a substitute should be requested from higher authority, and only their recommended substitution should be used.

Clean up all spilled or excess oil or grease after the aircraft is lubricated. Never allow oil or grease to come in contact with oxygen equipment. Some types of synthetic compounds are harmful to rubber, neoprene, and electrical material. They will also soften paint and should be removed as soon as possible with a clean cloth.

MAINTENANCE DOCUMENTATION

The numerous maintenance tasks that are performed on the line are never complete until the necessary maintenance documentation (MAF's, and SAF's, etc.) have been completed and turned in for processing. Throughout this manual various examples of this documentation have been shown with their intended use.

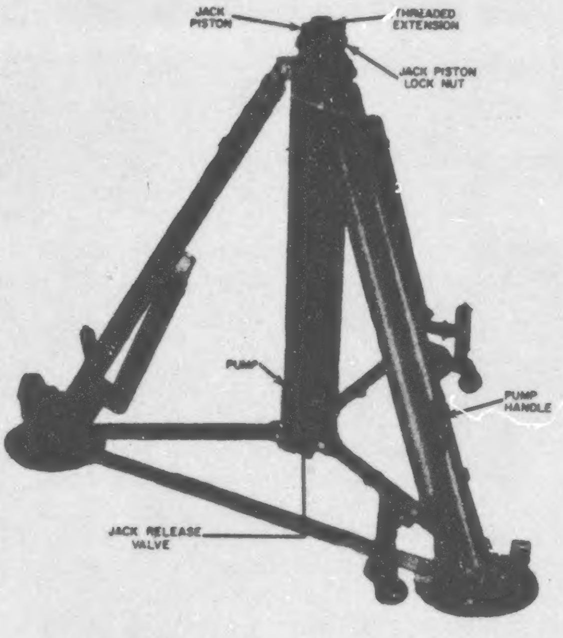
In order to achieve the highest possible state of aircraft readiness and reliability at the lowest cost in manpower, money, and material, maintenance documentation cannot be overstressed. Detailed instructions on the use and preparation of the various maintenance document forms are provided in Military Requirements for Petty Officer 3 & 2, NavPers 10056 (Series) and OpNav Instruction 4790.2 (Series).

AIRCRAFT JACKING

The AMS should be familiar with the jacking of an aircraft in order to be able to assist in performing routine maintenance. Since jacking procedures and safety precautions vary for different types of aircraft, only general jacking procedures and precautions are discussed in this chapter. Consult the applicable Maintenance Instructions Manual (General Information and Servicing section) for specific jacking procedures.

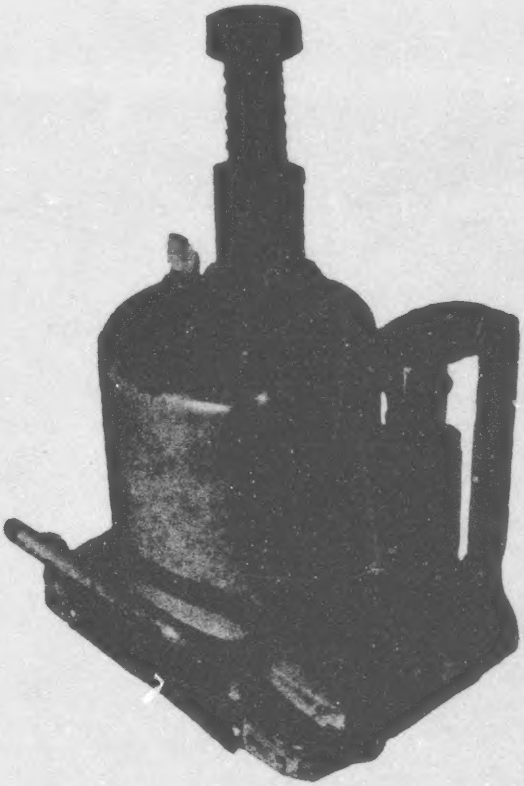
The aircraft to be jacked must be located in a level position, well protected from the wind. A hangar should be used if at all possible. The Maintenance Instructions Manual for the aircraft being jacked should be checked for the location of the jacking points. These jacking points are usually located in relation to the aircraft center of gravity so that the aircraft will be well balanced on the jacks. However, there are some exceptions to this. On some aircraft it may be necessary to add weight to the nose or tail to achieve a safe balance. Sandbags are usually used for this purpose.

Tripod jacks similar to the one shown in figure 12-23 are used when the complete aircraft is to be jacked. A small single-base jack similar to the one shown in figure 12-24 is used when only one wheel is to be raised. The jacks used for jacking aircraft must be maintained in good condition; a leaking or damaged jack must never be used. Also each jack has a maximum capacity, which must never be exceeded.



AM.216

Figure 12-23.–Typical tripod jack.



AM.217

Figure 12-24.–Typical single-base jack.

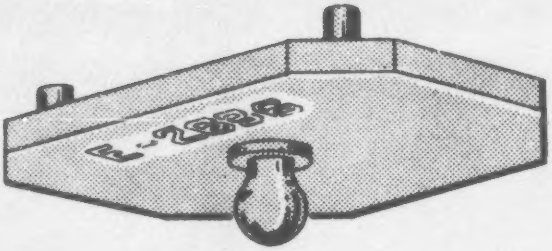
PROCEDURE FOR JACKING COMPLETE AIRCRAFT

Prior to the actual jacking of the aircraft, an overall survey of the complete situation should be made to determine if any hazards to the aircraft or personnel exist. Tripod jacks of the appropriate size for the aircraft being jacked should be placed under the aircraft jacking points and perfectly centered to prevent them from cocking when the aircraft is raised. The legs of the jacks should be checked to see that they will not interfere with the operations to be performed, such as retracting of the landing gear, after the aircraft is jacked.

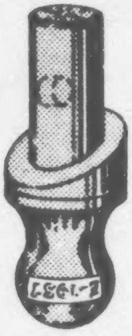
Jack pads, which are used as adapters between the jacks and the aircraft jacking points, are carefully installed and must fit perfectly. The jacks should be extended until they contact the jack pads. A final check for alignment of the jacks should be made before the aircraft is raised, as most accidents that occur during jacking are the result of misaligned jacks. Figure 12-25 illustrates two typical types of jack pads.

When the aircraft is ready to be raised a man should be stationed at each jack. The jacks should be operated simultaneously to keep the aircraft as level as possible and to avoid overloading any of the jacks. This can be accomplished by having the crew leader stand in front of the aircraft and give instructions to the men operating the jacks. Figure 12-26 illustrates an aircraft being jacked.

CAUTION: On many jacks the piston can be raised beyond the safety point; therefore, never



WING JACK PAD ASSEMBLY



FORWARD JACK FITTING

AM.218

Figure 12-25.—Typical jack pads.

raise an aircraft any higher than is necessary to accomplish the job at hand.

CAUTION: Avoid overextension of the threaded extension. While its compression strength is equal to the compression strength of the jack as a whole, its thin cross-sectional area makes it particularly susceptible to bending and breaking under side loads, especially when near its full extension.

NOTE: While jacking, the piston locknuts (fig. 12-23) should be moved down as the piston is raised. This will prevent the jack from collapsing in the event of a sudden loss of fluid. When jacking is complete, the locknuts should be locked snugly against the jack body.

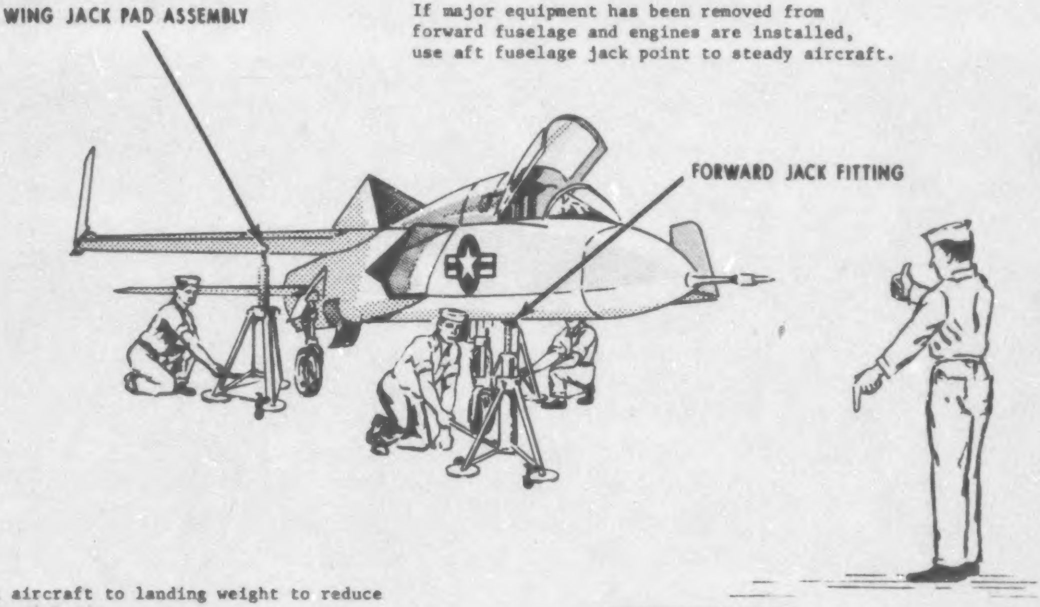
The area around the aircraft should be secured while the aircraft is on jacks. Climbing on the aircraft should be held to an absolute minimum, and no violent movements should be made by persons who are required to go aboard. Safety jacks or cradles designed to support the aircraft while on jacks should be put in place as soon as possible, particularly if the aircraft is to remain jacked for any length of time.

Jacking procedures aboard ship require an extra measure of caution because of ship movements. Permission to jack the aircraft must be given by the activity's maintenance control. No jacking will be authorized unless the weather is calm and the ship is expected to be on a straight course during the time the aircraft will be on jacks.

Figure 12-27 illustrates the shipboard jacking arrangement for the A-4E aircraft. Additional TD-1 tiedown chains may be utilized to anchor the jacks in position as a further measure of safety. Additional tiedown chains may also be added to landing gear and other tiedown attach points if drop checking operations permit.

When removing the aircraft from the jacks, insure that all obstructions, including stabilizing jack, are clear of the aircraft. The same number of people are required as for jacking. The jacks should be pumped up slightly to release the piston lock nuts. The locknuts should be turned upward on the piston screw threads at about the same rate as the pistons are descending. The level attitude of the aircraft should be maintained at all times. Removal of the jack pads from the jack receptacles should be accomplished as soon as the jack is moved clear. The weight of the pad is generally enough to cause the pad to fall out of its receptacle or if not removed immediately the possibility of overlooking their removal exists. In either case, a safety hazard is caused. More than one case of an aircraft flying with the jack pad in its receptacle has been recorded and points to the fact that human error can go undetected. While errors of this sort should have been noticed by the supervisor, quality assurance inspector, the plane captain, and the pilot who ultimately flew the aircraft, the maintenance man should not rely on others to see a job through to a safe completion.

NOTE: When lowering some aircraft from jacks, it is necessary to place metal plates (skid plates) under each tire on the main landing gear. These skid plates must have a film of grease



NOTE

If major equipment has been removed from forward fuselage and engines are installed, use aft fuselage jack point to steady aircraft.

1. Defuel aircraft to landing weight to reduce structural loads.
2. Inflate landing gear struts. See Warning note.
3. Install forward fuselage and wing jack pads.
4. Jack wing and forward fuselage points evenly.
5. When aircraft is jacked to desired height, set ram safety nuts.

WARNING

- Lower aft fuselage jack before any other jacks to prevent structural damage.
- Do not use more than 1000 PSI air-source when inflating struts.

AM.219

Figure 12-26.—Jacking a complete aircraft.

between them to allow the upper plate to skid as the weight of the descending aircraft increases, permitting the main gear to assume its neutral rest position (See fig. 12-28.)

PROCEDURE FOR JACKING ONE WHEEL

When only one wheel has to be raised, as for changing a tire or greasing wheel bearings, a single-base jack is used. Before the wheel is raised, the remaining wheels must be chocked fore and aft to prevent movement of the aircraft. If the aircraft is equipped with a tailwheel, it must be locked. The wheel should be raised only high enough to clear the deck. Figure 12-29 shows a wheel being raised using a single-base jack.

MISCELLANEOUS GROUND HANDLING EQUIPMENT

When assigned to the line division, the AMSAN AMS3 may be required to assist in the starting of aircraft engines or ground testing of various items of aircraft equipment. To do this it will be necessary to know how to operate

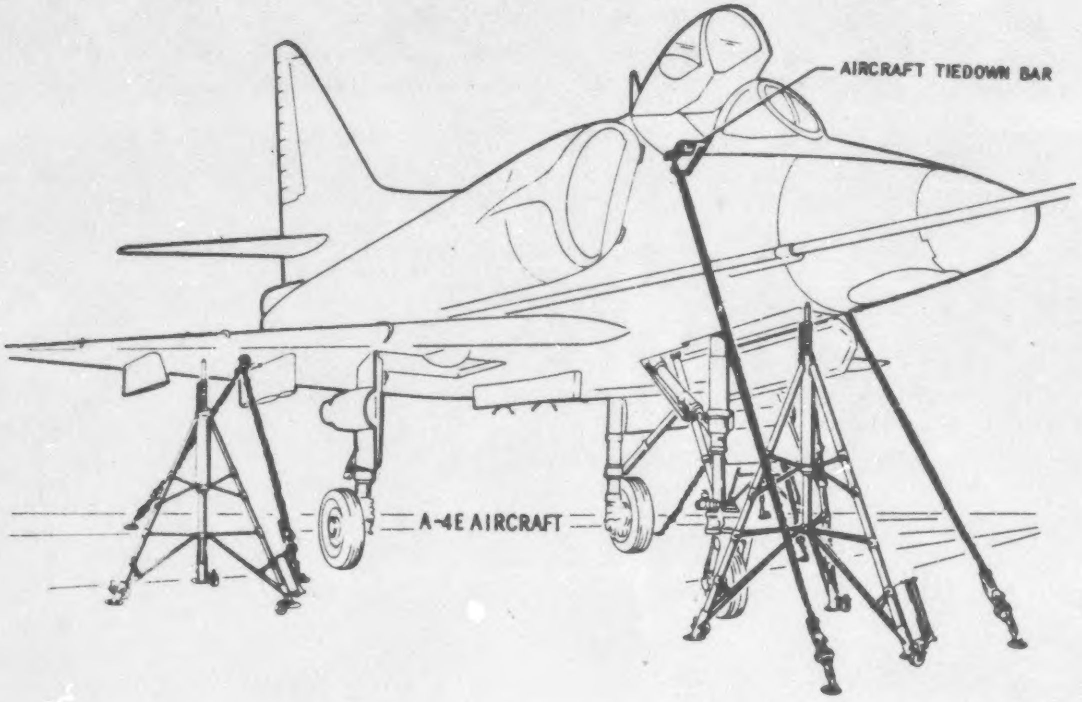


Figure 12-27.—Shipboard jacking arrangement—A-4E.

equipment such as mobile electric powerplants and gas turbine compressors. Special training and in some cases licensing is required of operators of such equipment.

MOBILE ELECTRIC POWERPLANTS (MEPP)

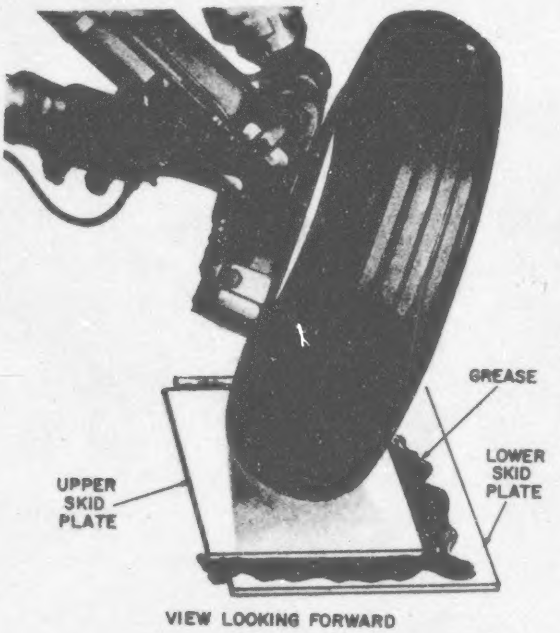
There are many different types of mobile electric powerplants in common use. Some types are self-propelled and others must be pushed or towed to the aircraft which is to be serviced. The NC-5, NC-7, NC-10/10A, NC-12 and 12A, and the Mobile Motor Generator (MMG) units are still in use throughout the Navy and possess similar controls and operating features. Since special training is required and provided by ground support equipment personnel to insure that such equipment is operated only by fully qualified operators, only brief descriptive coverage is provided in this manual on the NC-5 and the NC-7B.

Operation and servicing instructions for the various types of mobile electric powerplants can be located by referring to the applicable NavAir 19 (Series) Operating and Servicing Manual for the specific model equipment as listed in the NavAir Publications Index, NavAir 00-500A.

NC-5 Power Unit

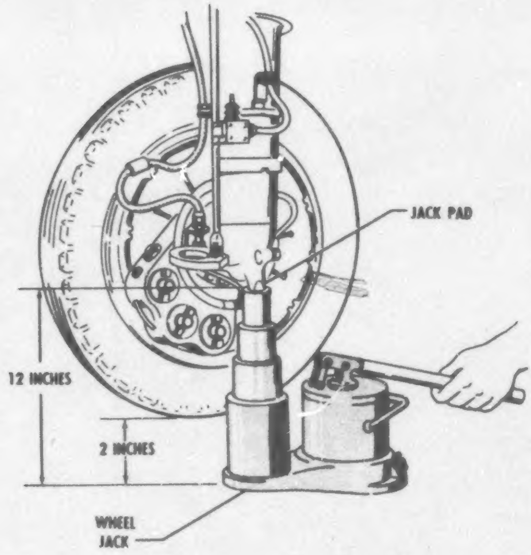
The NC-5 is a self-propelled electric power unit. It may be driven from place to place in the same manner as any other motor vehicle.

It has provisions for delivering three different kinds of power—constant voltage variable current d-c electrical power for starting jet aircraft engines; constant voltage d-c power for starting reciprocating aircraft engines or jet aircraft engines in aircraft having a single bus type electrical system; and 115/200-volt,



AM.1227

Figure 12-28.–Skid plate.



AM.220

Figure 12-29.–Jacking one wheel.

3-phase, 400-Hz alternating current for checking and operating a-c equipment, each through a separate cable.

The power cables are plugged into the aircraft electrical system at an external power receptacle. Figure 12-30 shows the NC-5 and the external power receptacle similar to that found on most new aircraft. Aircraft with this type external power receptacle require the use of only one type power, 115/200-volt, 400-Hz alternating current (a.c.).

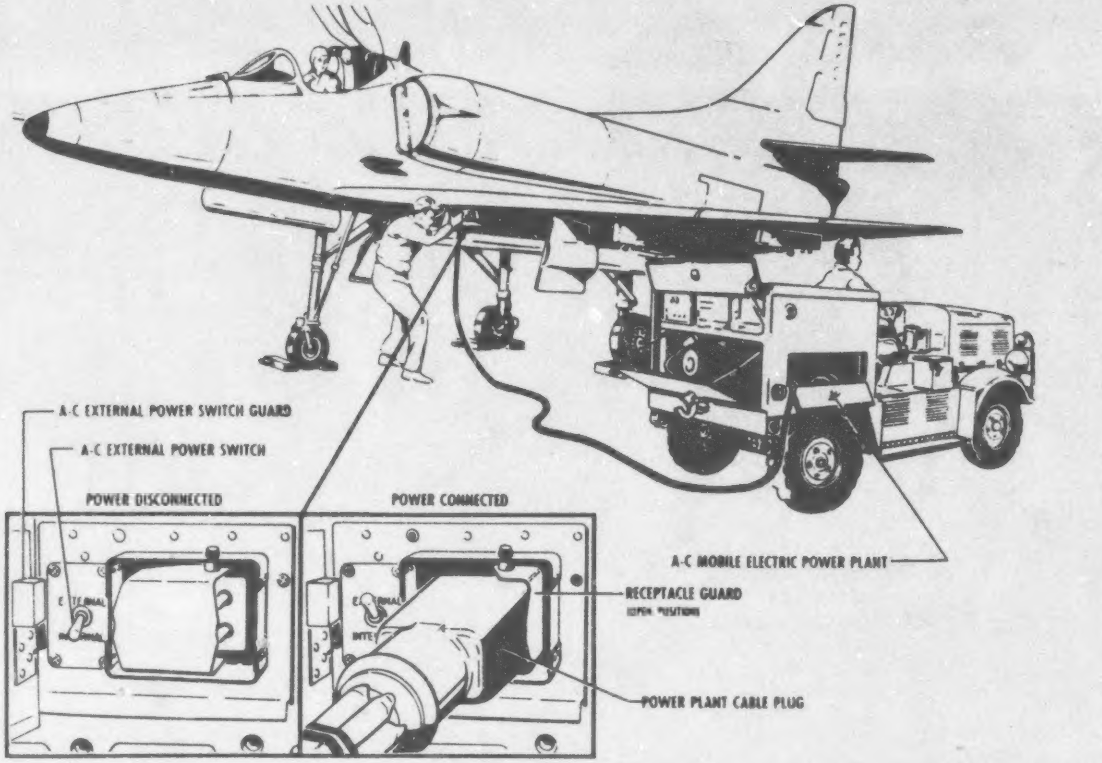
Some aircraft require the use of 28-volt direct current (d.c.) for starting reciprocating engines. Figure 12-31 shows the external power receptacle used on an aircraft which requires both 400-Hz a.c. and 28 volt d.c. NOTE: The shape of the plug and the spacing of the pins in the receptacle make it impossible to plug the wrong type cable into the aircraft.

When applying electrical power to an aircraft, park the NC-5 in a position so that the cable will reach without causing a load on the external power receptacle. The weight of the cable might cause damage to the structure around the receptacle.

Insure that the power unit exhaust is not near the skin of the aircraft. The heat from the exhaust could cause damage to the skin or the paint finish.

Servicing an aircraft with an NC-5 should always be a two-man job. The driver should remain at the wheel and operate the generator drive unit and the throttle. The second man should operate the unit's electrical system and plug the power cables into the aircraft.

Before engaging the generator drive unit, make sure that the transmission is in neutral. Much damage is caused throughout the Navy by carelessness in the operation of mobile electric power units. No one should attempt to operate any type of mobile electrical equipment unless he is a qualified operator. NOTE: Ground support equipment schools are being operated at all naval air stations to train operators of units such as the NC-5. All activities require a special operator's permit for the operators of these units.


A-C EXTERNAL POWER SWITCH GUARD
A-C EXTERNAL POWER SWITCH
POWER DISCONNECTED
POWER CONNECTED
A-C MOBILE ELECTRIC POWER PLANT
RECEPTACLE GUARD
(OPEN POSITION)
POWER PLANT CABLE PLUG

AM.221

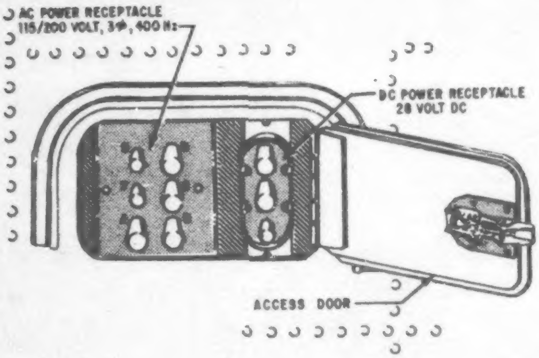
Figure 12-30.—External power application using NC-5 mobile electric power unit.

After completing the turnup or checkout of equipment, the power cable should be removed from the external power receptacle and stowed in the container which is provided on the unit. Many times a year aircraft are damaged by careless NC-5 operators driving off from the aircraft with the cable still plugged in. Care should be taken to insure that the cable is not dragged on the taxi way behind the power unit. Dragging severely damages the cable, and cables are quite expensive. Before driving the unit away from the aircraft, check to insure that the generator drive unit is disengaged.

NC-7 Electric Power Unit

The NC-7 shown in figure 12-32 is powered by a V-8 gasoline engine and contains two d-c generators, an a-c generator, a control console for control of the engine and both electrical systems, and a propulsion system for moving the unit under its own power. Access doors are provided for the control, console, engine, battery, cable stowage, and tool compartments.

The a-c electrical power system provides 120/208-volt 3-phase, 400-Hz power for servicing aircraft a-c components. The d-c generators provide an output of 28 volts and are rated at 750 amperes continuous and 1,000 amperes intermittently. The outputs from the two d-c generators are used for jet engine starting and servicing d-c components. Also, the output from one of the d-c generators is used to power the self-propulsion system.



AM.223

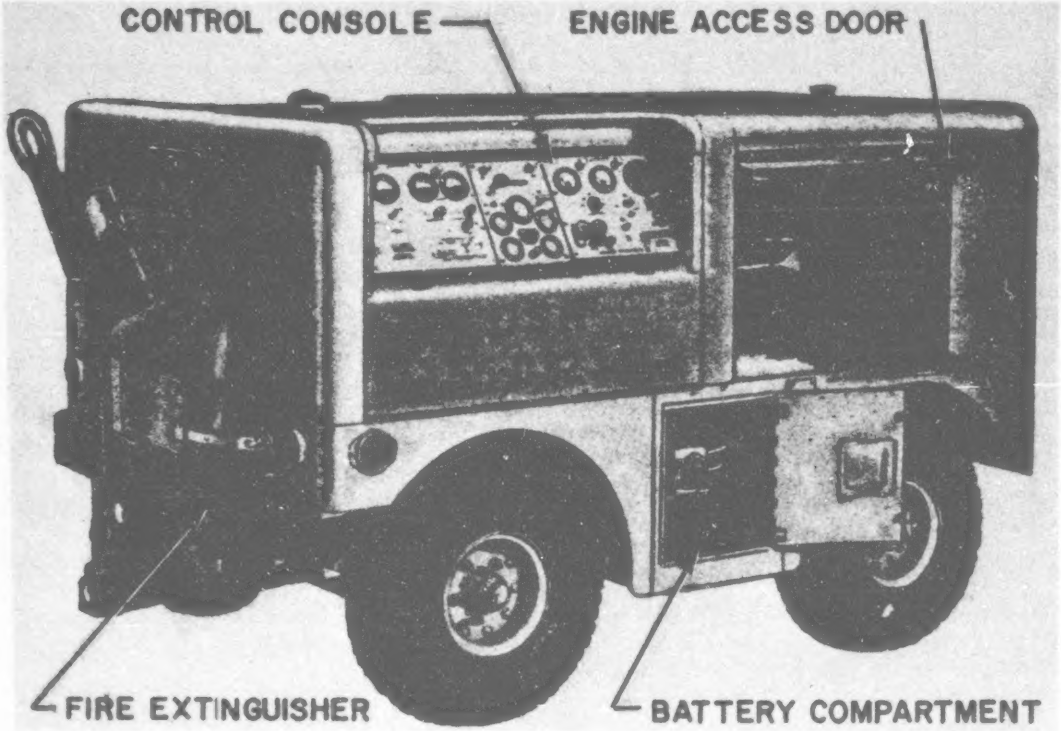
Figure 12-31.–External power receptacle.

A hand control unit is provided on the tow bar for controlling the unit during self-propelling operations.

CAUTION: Do not move the power unit by means of the self-propulsion mechanism while supplying power to an aircraft. Under no condition is the unit to be used as the prime mover for towing other equipment.

The self-propelling feature should be used only when moving from one aircraft to another or from the line to the hangar and back as necessary if the distance is not too great. For greater distances the unit should be towed.

Most of the electrical power units tend to be slightly topheavy. When driving or towing such units the speed should be held to a minimum to prevent the possibility of turning the unit over. For example, the towing speed for the NC-7 is 20 MPH maximum.



AM.1214

Figure 12-32.–Mobile Electric Powerplant (NC-7B).

GAS TURBINE COMPRESSORS

The gas turbine compressor is used to provide pneumatic power in the form of compressed bleed air for the operation of pneumatic equipment. Such as aircraft engine starters and air-conditioning systems, and for testing units such as the ram-air turbine. Gas turbine compressors are largely self-contained and require only an outside source of fuel and oil to maintain a constant output.

The model NCPP-105 compressor power unit, shown in figure 12-32, is a complete, self-contained unit consisting of a flyaway assembly enclosed in a skid-mounted, weather-resistant enclosure. Some models of the NCPP-105 are mounted on trailers for ease of movement from aircraft to aircraft or place to place. The NCPP-105 supplies compressed air, at two pressure ratios (5:1 and 3.6:1), for aircraft engine starting, and a-c and d-c electrical power for operation of aircraft a-c and d-c electrical components. The NCPP-105 is equipped with a remote cable assembly, an a-c output cable, a d-c output cable, and a bleed air duct assembly.

The unit enclosure consists of a forward and aft enclosure (hinged together), a cable stowage enclosure, muffler assembly, fuel tank, structure assembly, and a base assembly.

The flyaway assembly, shown in figure 12-34, is normally operated while in the NCPP-105 unit enclosure, with the d-c power supply mounted in the forward enclosure. However, when it is required to transport the flyaway assembly by aircraft to a temporary location, the d-c power supply is removed and relocated on the flyaway assembly structure. The fuel line and a-c and d-c electrical output cables are disconnected, the forward and aft enclosures are lifted off the structure assembly, and the flyaway assembly is then removed from the base assembly. The flyaway assembly, with its remote cable, a-c and d-c electrical output cables, and bleed air duct assembly, upon arrival at its temporary location, can be operated by attaching it to a fuel supply.

NOTE: The NCPP-105 flyaway assembly cannot be hung as an external store and must be transported inside a transport or cargo type aircraft.

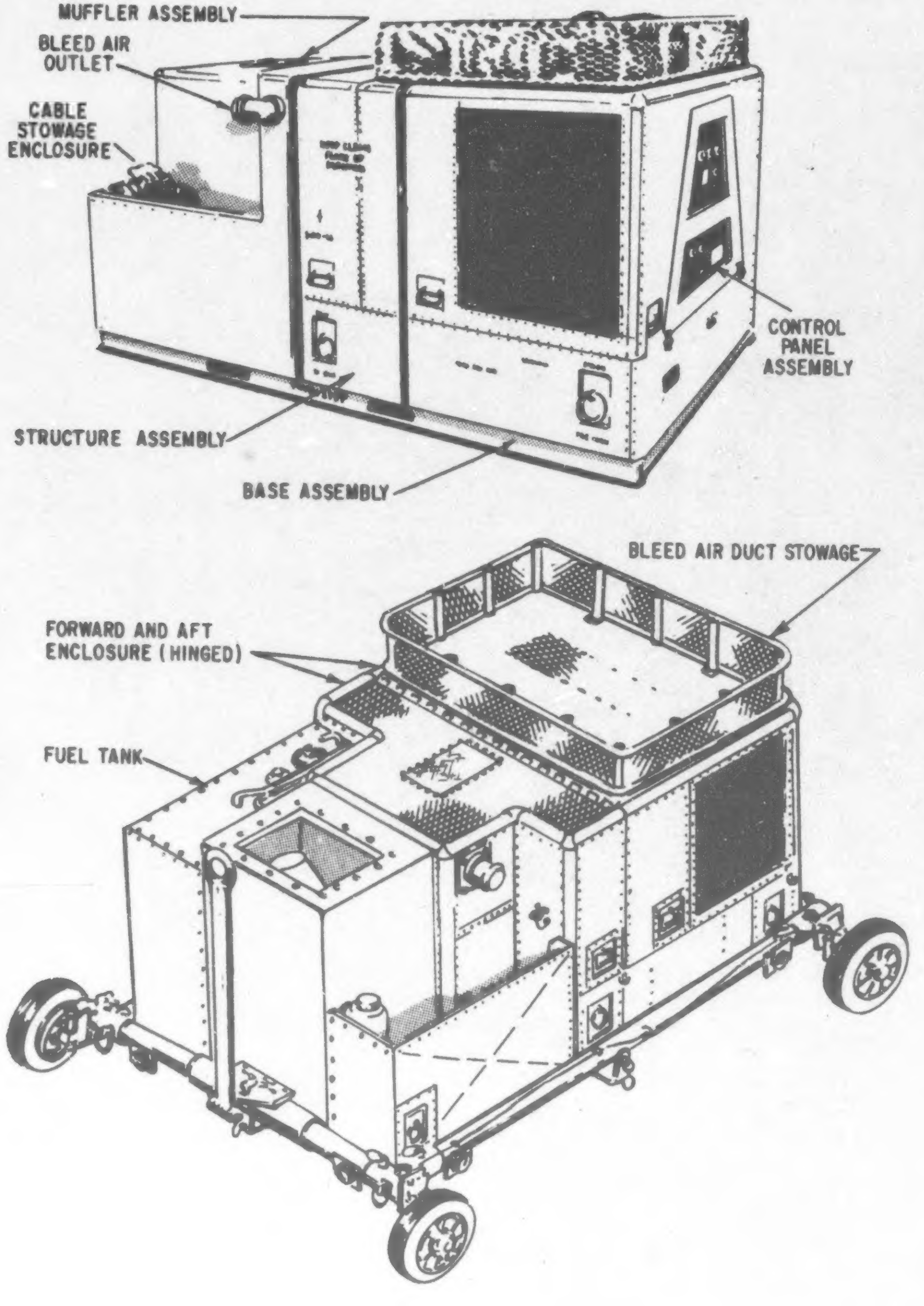
The control panel, shown in figure 12-35, is part of the flyaway assembly and is located on one end of the NCPP-105 unit. The control panel contains the operating instructions for the operation of the unit. Table 12-1 is a list of all the controls, indicators, and connectors located on the NCPP-105 control panel and should be used in conjunction with figure 12-35.

The NCPP-105 is intended for ground use only and because it is skid-mounted, should be strategically placed along the line so that it can be used to service more than one aircraft without having to be moved.

Only qualified operators should attempt to operate this type equipment. Training on this type equipment is usually included in the aviation support equipment school operated at naval air stations.

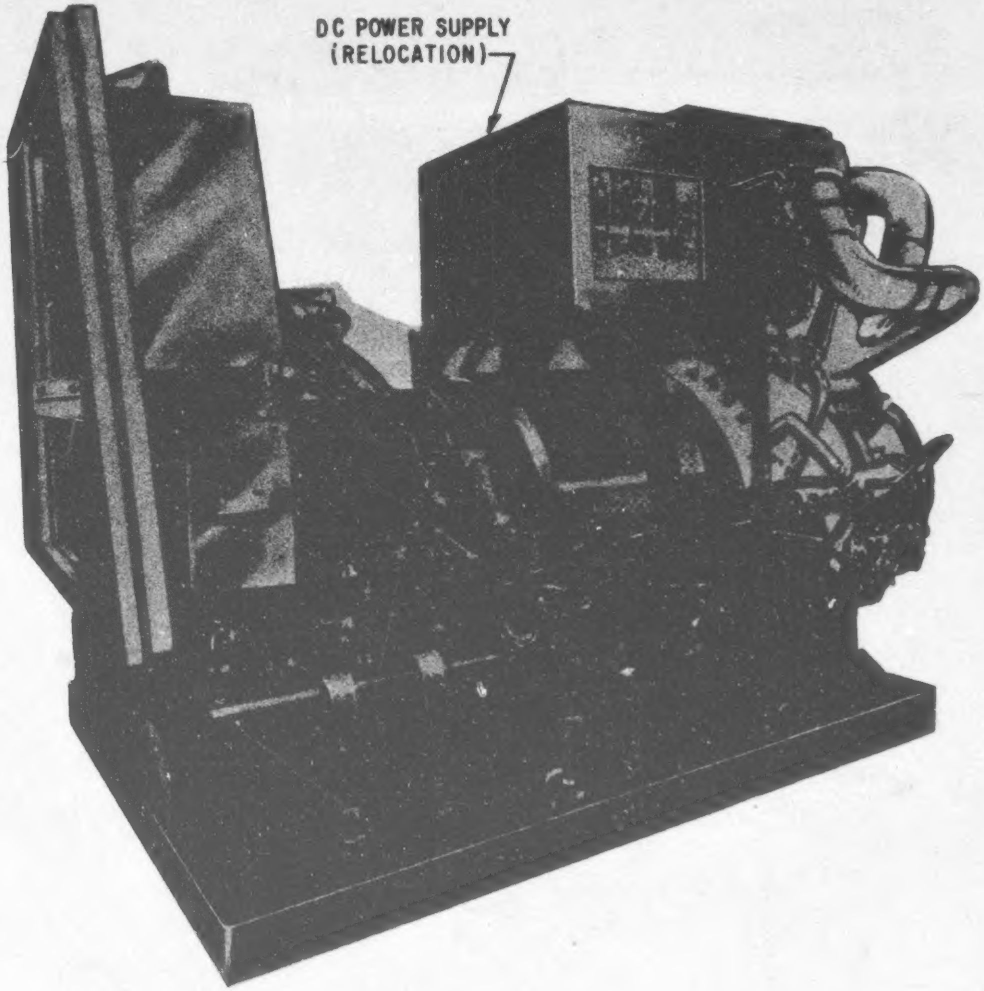
Gas turbine compressors may be damaged by trash, tools, or other foreign objects which may be left near the inlet duct. When the compressor is operating, the following precautions should be adhered to:

1. Stand clear of the air inlet. Like aircraft jet engines, these units take in large quantities of air.
2. Stand clear of the exhaust, and position the unit so that the exhaust does not strike the aircraft.
3. Stand clear of the plane of rotation of the turbine compressor. This area is clearly defined and marked on the equipment.
4. Do not connect or disconnect the ducting while the unit is operating.
5. Do not connect or disconnect the electrical cables while the switches are ON.
6. After servicing the aircraft, always stow the cables and ducting in the space designed for them.



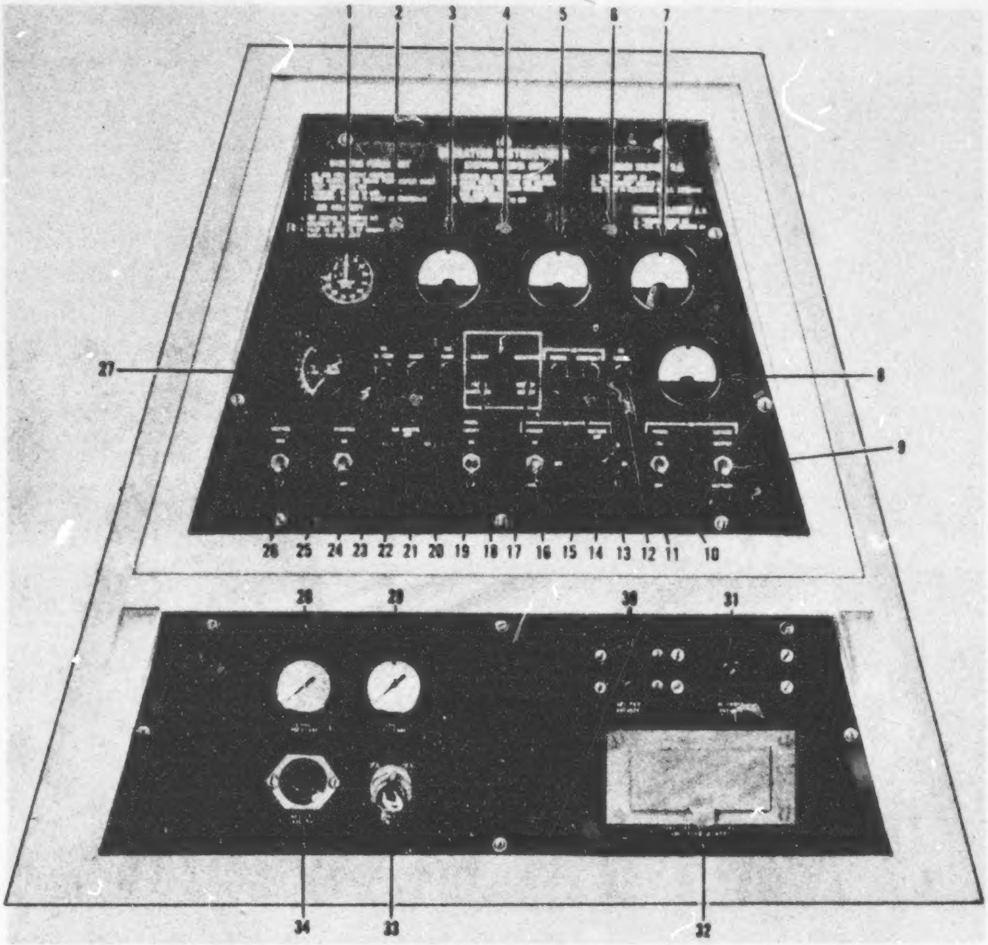
AM.903

Figure 12-33.—Model NCPP-105 compressor power unit.



AM.904

Figure 12-34.—NCPP-105 flyaway assembly.



AM.905

Figure 12-35.–NCPP-105 control panel.

Table 12-1.—Controls, indicators, and connectors—NCPP-105.

Index No. (figure 12-3)	Nomenclature	Function	Preliminary Setting or Indication
1	Indicator (M1)	Indicates engine rpm in percentage.	zero
2	Dome Assembly (DS7)	Illuminates panel.	off
3	Meter (M6)	Indicates a-c voltage.	zero
4	Dome Assembly (DS8)	Illuminates panel.	off
5	Meter (M5)	Indicates a-c amperes.	zero
6	Dome Assembly (DS9)	Illuminates panel.	off
7	Meter (M4)	Indicates d-c amperes.	zero
8	Meter (M3)	Indicates d-c voltage.	zero
9	Switch (S8)	Selects meter indication of output or battery.	OFF
10	Switch (S7)	Controls d-c power.	OFF
11	Dome Assembly (DS4)	Indicates d-c power.	off
12	Dome Assembly (DS6)	Indicates a-c overvoltage.	off
13	Dome Assembly (DS5)	Indicates a-c power.	off
14	Switch (S6)	Selects meter indication of a-c phase.	OFF
15	Dome Assembly (DS11)	Illuminates panel.	off
16	Switch (S5)	Controls and resets a-c power output.	OFF
17	Circuit Breaker (CB2)	Controls control circuit.	off
18	Circuit Breaker (CB1)	Controls power switches.	off
19	Switch (S4)	Controls panel lights.	OFF
20	Dome Assembly (DS10)	Illuminates panel.	off
21	Switch (S3)	Selects air ratio output.	OFF
22	Dome Assembly (DS2)	Indicates airflow.	off
23	Dome Assembly (DS1)	Indicates ready for power delivery.	off
24	Dome Assembly (DS3)	Indicates high oil temperature.	off
25	Switch (S2)	Controls power to starter relay.	off
26	Switch (S1)	Controls power to panel.	off
27	Indicator (M2)	Indicates engine exhaust temperature.	zero
28	Gage	Indicates engine air pressure.	zero
29	Gage	Indicates engine oil pressure.	zero
30	Circuit Breaker (CB3)	Controls power to starter.	closed
31	Circuit Breaker (CB5)	Controls d-c power to output cable.	closed
32	Receptacle (J12)	Auxiliary d-c starting and charging input.	–
*33	Receptacle (J10)	Connection for remote cable.	–
34	Plug (J11)	Provision for battery heater.	–

*Used on power units bearing Part No. 64A90-F1. For power units bearing Part No. 64A90-F1-2, connection for remote cable is located on the aft enclosure.

INDEX

Accessories manuals, 22
Acrylic lacquer, 317-318
Advancement, 3-10
  active duty requirements, 5
  inactive duty requirements, 6
  preparing for, 4-10
  qualifying for, 4
Air storage bottle servicing, 360-361
Aircraft Application List, 14
Aircraft cleaners, 288-290
Aircraft cleaning equipment, 290-291
Aircraft cleaning procedures, 291-293
Aircraft handling:
  firefighting procedures, 346-347
  protective covers, 340-341
  safety precautions, 341
  spotting aircraft, 337
  surface control locks, 338
  taxi signalman, 333-334
  taxi signals, 334
  tiedown procedures, 337-340
  tow bars, 335-337
  towing aircraft, 334-335
Aircraft jacking, 368-371
Aircraft lubricants, 363-364
Aircraft manuals, 17-22
Aircraft preservation, 295-298
Aircraft servicing, 347-363
  air bottles, 360-361
  air compressors, 359
  defueling, 351-352
  engine oil, 352-354
  fueling, 347-351
  hydraulic system, 354-355
  pneumatic system, 355, 357-361
  shock struts, 359-360
  tire inflation, 362-363
Aircraft spotting, 337
Aircraft tiedown, 337-340
Aircraft tires:
  Construction, 239-244
    identification, 243-244
    tread, 240-241
    types, 242
  inflation, 252-253, 362-363
  maintenance, 245-246
  mounting and dismounting, 246-252
  preventive maintenance, 254-256
  retreading and repair, 253-254
  storage, 244
Airframe construction:
  fixed wing, 57-72
    arresting gear, 71
    control surfaces, 63-66
    flaps, wing, 65
    fuselage, 57-59
    landing gear, 66-72
    slats, 66
    speed brakes, 66
    spoilers, 65-66
    spring tabs, 65
    stabilizers, 62-63
    tabs, spring, 65
    tabs, trim, 64-65
    tail gear, 69-71
    tail skag, 71-72
    wings, 59-62
  rotary wing, 72-76
    fuselage, 72
    landing gear, 72-73
    pylon, 75-76
    rotary rudder blades, 76
    rotary rudder head, 76
    rotor head, 75
    rotor wing, 74-75
Airloc fasteners, 127-128, 207-209
Air valves, 360
Aliphatic naphtha, 288
Allowance lists, 17
Alloying of metals, 35
Aluminum alloys, 37-42
Aluminum, corrosion of, 302
AM rating, 1-3
  duties, 3
  paths of advancement for, 1-2

Approach magazine, 27
Armed aircraft precautions, 345
Aromatic naphtha, 288-289
Arresting gear, 71

Bar folder, 112
Bars, tow, 335-337
Bellcranks, 154
Bend allowance, 114-116
Beryllium copper, 43
Blast, vapor, dry honing, 310-314
Blind rivets, 121-123, 188-197
Bolts, 129-133
Brake:
  box and pan, 111-112
  cornice, 109-111
Brakes, overheated, 342-345
Bronzes, 42-43
Bucking bars, 87-88
Bulletins, 24-26
Bungees, 154

Cables, 146-147
  fittings, 147
  guides, 150
Cadium, corrosion of, 303
Camloc fasteners, 125-126, 203, 205-206
Carbon steels, 36
Casting alloys, aluminum, 41
Changes, aircraft, 24-26
Chrome-molybdenum steel, 37
Chrome-nickel (stainless steels), 37
Chrome-vanadium steels, 37
Chromium steels, 37
Clamps, installation of, 281-282
CO_2 bottles, 346
Compressors, 359
Connector links, adjustable, 149
Controls, mechanical, 144-154
  cable system, 146-154
    cable fittings, 147
    cable guides, 150, 152
    cables, 146-147
    connector links, adjustable, 149
    pulleys, 152-153
    quick disconnects, 149, 151
    sectors and quadrants, 153-154
    turnbuckles, 148-149
  rigid control systems, 154
    bellcranks and walking beams, 154
    bungees, 154
    idler arms, 154
    push-pull rods, 154
Copper and copper alloys, 42-43
Copper, corrosion of, 302-303
Corrosion control, 284-332
  appearance of corroded parts, 302-303
  chemical surface treatments, 314-316
    corrosion control kit, 315-316
  corrosion elimination, 306-316
    removal of corrosion, 307-314
      vapor blasting, 309-314
    removal of paint, 307
  corrosion prone areas, 298-302
  covers and shrouds, 293, 295
  damage limits, 314
  detection methods, 45-51, 306
    penetrant inspections, 45-51
      interpreting results, 50-51
  forms of corrosion, 303-306
  ground handling requirements, 295
  painting, aircraft, 316-328
  preservation, aircraft, 295-298
  preventive maintenance, 287-298
  sealants, 328-332
  surface maintenance, 287-293
    cleaning methods, 291-293
    materials, 288-290
  Vacu-Blast dry honer, 310-314
Countersinking:
  dimple, 181-185
  machine, 185
Coupling, V-band, 144
Covers and shrouds, use of, 293-295
Cutting tools, 90-91

Damage classification, 155
Defueling, 351-352
Dimpling, hot, 181-185
Directional flight, 83 84
Directives Application List, 14
Dissimilar metal corrosion, 305
Drilling rivet holes, 179-180
Drycleaning solvent, 288
Dye penetrant inspection, 45-52
Dzus fasteners, 128, 206-207

Edges, reinforced, 112-113
Ejection seat hazards, 342
Electric power units:
  NC-5, 372-374
  NC-7, 374-375

Emulsion cleaners, 289
Enamel finishes, aircraft, 319
Engine oils, 352-354
Enlisted rating structure, 1
Epoxy primer, 317
Equipment Applicability List, 13-14
Equipment and Subject Applicability List, 14
Extractors, screw and bolt, 98

Fasteners:
  Heli-Coil inserts, 133-134
  Hi-Lok, 133
  Jo-Bolt, 134
  lockbolt, 124
  miscellaneous:
    pins, 140-141
      cottes, 141
      flathead, 140-141
      tapes, 140
    rivets (See Rivets.)
    skin:
      Cleco, 88-89
    threaded, 129-134
      bolts, 129-133
        heads, 130-131
        identification, 131-133
        material, 131
        threads, 131
    nuts, 135-136
    nonself-locking, 135
    self-locking, 135-136
  screws, 139-140
    machine, 139-140
    self-tapping, 140
    setscrews, 140
    structural, 139
  turnlock, 124-128
    Airloc, 127-128
    Camloc, 125-127
    Dzus, 128
Fatigue corrosion, 305
Ferrous aircraft metals, 35-37
Filiform corrosion, 306
Firefighting procedure, 346-347
Flaps, wing, 65
Flared-tube fittings, 261
Flareless-tube fittings, 261
Flexible hose (rubber), 274-279
  fabrication and replacement, 276-277
  installation, 277-279
Flight control surfaces, 63-66
  basic controls, 63-64
  miscellaneous flight controls, 64-66
    slats, 66
    speed brakes, 66
    spoilers, 65-66
    spring tabs, 65
    trim tabs, 64-65
    wing flaps, 65
Flight control systems:
  maintenance, 213-224
    control cable, 213-218
    push-pull linkage, 218
    removal and installation, 222-223
    rigging, 220-222
    troubleshooting, 218-220
  rigging rigid controls, 221-222
    balance, 223-224
  turnbuckles, 221
Flight deck safety, 345
Flight line safety, 341-345
Fluid line identification, 258-259
Flush patch, 160-163
Forms of corrosion, 303-306
Fretting corrosion, 305-306
Friction lock rivets, 122, 188-189
Fuselage (fixed-wing), 57-59
Fuselage (rotary-wing), 72
Fuselage sections, aft, 224-227
  installation, 225-227
  removal, 224-225

Galvanic metal corrosion, 305
Gas turbine compressors, 376
Gravity fueling, 349

Handtools, 86
Hardness testing methods, 36
Heat treatment, 33-35
Heli-Coil inserts, 133-134
Hi-lok fasteners, 133, 199-201
Hi-Shear rivets, 120-121, 197-199
Hole finder, 88
Hose, flexible:
  rubber, 274-279
  Teflon, 279-281
Hovering, 81-83
Hydraulic fill stand, 355
Hydraulic system servicing, 354-355

Identification of aluminum, 38-40
Idler arms, 154
Illustrated Parts Breakdown, 21
Inner tubes, 256-257
Inspection of metals, 45-52
  penetrant, 46-51
  interpreting result, 50-51
Instructions and Notices, 26-27
Intergranular corrosion, 304-305
Iron and steel, corrosion of, 302

Jack pads, 369-370
Jacking, 369-371
Jo-Bolt, 134, 202-203

K-Monel, 43

Landing gear (fixed-wing), 66-72
  arresting gear, 71
  main landing gear, 67-69
  nose gear, 69-70
  tail gear, 69-71
  tail shag, 71-72
Landing gear (rotary-wing), 72-73
  main landing gear, 73
  tail landing gear, 73
Lap patches, 159-160
Layout practices, 116, 118
Leadership, 3
Letter type publications, 24-27
Line operations, 333
Lock rivets:
  friction, 122
  mechanical, 122
Lockbolt, 124, 199
Locking devices, 338
Lubricants, 363-365
Lubrication charts, 366

Machine screws, 139-140
Magnesium and magnesium alloys, 43-44
Magnesium, corrosion of, 302
Main landing gear, 67-69
Maintenance Instructions Manuals, 18-20
Manual type publications, 16-24
MECH, 27
Mechanical cleaning materials, 289-290
Mechanical lock rivets, 122, 189-194
Metal cutting equipment, 100-102
  shears:
    hand bench, 102
    squaring, 101
    throatless, 101-102
    unishear, 102
  turrent punch, hand operated, 102
Metal forming machines,
  bar folder, 112
  brake: 109-112
    box and pan, 111-112
    cornice, 109-111
  rotary machine, 105-107
    slip-roll forming machine, 102-105
Metal lip-seal fittings, 261-262
Metal working processes, 31-33
Metals, aircraft, 28-45
  alloying of, 35
  ferrous aircraft metals, 35-37
    hardness testing, 36
    SAE numerical index, 35-36
    types, characteristics, and uses, 36-37
  heat treatment, 33, 35
    aluminum and its alloys, 37-42
    copper and copper alloys, 42-43
    magnesium and magnesium alloys, 43-44
  nonferrous aircraft metals, 37-44
    titanium and titanium alloys, 42
  properties, 28-30
  qualities, 30-31
  substitution and interchangeability, 45
Methyl ethyl ketone (MEK), 289
Microbiological corrosion, 306
Mineral spirits, 288
Monel, 43

NATOPS Flight Manual, 17
Naval Aviation News, 27
NavTra 10052, 9
Navy Training Manuals, 9-10
NC-5 power unit, 372-374
NC-7 power unit, 374-375
Nickel, corrosion of, 303
Nickel steels, 37
Nitrogen trailer, 357-359
Nonferrous aircraft metals, 37-44
Nonmetallic materials, 52-56
NT-4 tow bar, 335-337
Numerical Sequence List, 12-13
Nuts, aircraft. (See Fasteners)

Outfitting Lists, 17

Packaging and barrier materials, 298
Paint removal, 307

Painting, aircraft, 316-328
Paints, aircraft, 317-319
Patches:
  flush, 160-163
  lap, 159-160
Penetrant inspection, 45-52
Periodic Maintenance Requirements Manual, 20
Personnel Qualification Standards (PQS), 7-8
Plane director, 333-334
Plastic enclosures, transparent, 52-55, 227-232
  installment of panels, 230-232
  removing scratches, 228-230
  surface cleaning, 227-228
Plastics:
  reinforced, 55-56, 165-173
  transparent, 52-55
Pneumatic system servicing, 355, 357-361
Polyurethane finishes, aircraft, 318-319
Powerplants, mobile, 372-375
Preservation materials, 296-297
Preservation of aircraft, 295-298
Presetting, flareless-tube fittings, 267-269
Pressure fueling, 349-351
Pressure oiling, 352-354
Protective covers, 293-295, 340-341
Publications, aeronautic, 12-27
  Index, 12-16
    Aircraft Application List, 14
    Directives Applications List, 14
    Equipment and Subject Availability List, 14
    Equipment Applicability List, 13-14
    Numerical Sequence List, 12-13
    Updating, 15
  letter material, 24-27
    Bulletins, 24-26
    Changes, 24-26
    Instructions and Notices, 26-27
    Technical Directives, 24-26
  manuals, 16-24
    accessories, 22
  aircraft, 17-22
    flight manual (NATOPS), 17
    general aircraft manuals, 22
    IPB, 21
    MIM, 18-20
    PMRM, 20
    structural repair, 20
    weight and balance, 21-22
  safety precautions, 23
  support equipment, 23-24
  technical information file of support equipment, 23-24
  numbering system, 16, 25
    letter material, 25
    manuals, 16
  security of, 15-16
Pulleys, 152-153
Push-pull rods, 154
Pylon, 75-76

Qualifications Manual, 4-7
Quick disconnects, 149

Rapid Action Change (RAC) System, 16
Rating structure, 1
Reading List, iv
Record of Practical Factors, 8
Refueling aircraft, 347-351
Repair material, 157
Repair, trailing edge, 177
Rig pins, 99
Rigid tubing, 259-262
Rivet cutters, rotary, 86-87
Rivet head shaver, 94
Rivet installation:
  blind, 188
  friction lock tools, 188
Rivet removal, 186-187
Rivet set, 87
Riveters, pneumatic, 94-97
Riveting:
  flush, 180
  procedure, 177-178, 185-186
Rivets:
  blind, 121-123
    pull-through, 122
    Rivnut, 122-123
    self-plugging, 122
  High-Shear, 120-121
    identification, 121
  solid, 119-120
    composition, 120
    identification code, 119-120
Rivnut, 122-123
  installation of, 194-197
Rotary machine, 105-107
  beading, 105-106
  burring, 106-107
  crimping, 106
  turning, 106
  wiring, 106

Rotary rudder blades, 76
Rotary rudder head, 76
Rotor head, 75
Rotor wing, 74-75
Rubber hose, flexible, 274-279

Safety precautions:
  armed aircraft, 345
  engine noise, 341-342
  exhaust area hazards, 341
  flight deck, 345
  foreign object damage, 346
  fueling, 347-349
  intake duct hazards, 342
  overheated brakes, 342-345
  seat ejection mechanisms, 342
Safety Precautions Manual, 23
Safety wire, 141-142
Sandwich construction, (honeycomb and balsa wood core), 56, 173-176
Screws (See Fasteners.)
Sealants, 328-329, 331-332
Sealants, application of, 329-331
Seams, sheet metal, 113-114
Sectors and quadrants, 153-154
Self-tapping screws, 140
Setscrews, 140
Shears, 101-102
  hand bench, 102
  squaring, 101
  throatless, 101-102
  unishear, 102
Skin repairs, 157, 159-165
Skin replacement, 163-165
Slats, 66
Slip-roll forming machine, 102-105
Solvent-emulsion cleaning, 289
Solvents, 288-289
Spanner wrenches, 90
Speed brakes, 66
Spoilers, 65-66
Spring tabs, 65
Stabilizers, 62-63
Stainless steels, 37
Stress corrosion, 305
Striking tools, 89
Structural Repair Manual, 20
Support Equipment Manuals, 23
Surface control locks, 338
Surface maintenance, 287-293

Tail gear, 69-71
Tail skag, 71-72
Taps and dies, 98
Taxi signalman, 333-334
Taxi signals, 334
TD-1 tiedown, 337-338
Technical Directives, 24-26
Technical Information File of Ground Support Equipment, 23-24
Teflon hose, flexible, 279-281
Tensiometer, 90, 93
Theory of flight (rotary wing), 76-84
Threaded fasteners, (See Fasteners.)
Throw boards, 99-100
Tiedown, aircraft:
  afloat, 337-338
  ashore, 338-340
Tire inflation, 252-253
Tires, aircraft, 238-256
Titanium and titanium alloys, 42
Titanium, corrosion of, 303
Tools:
  custody, 85-86
  inventory, 86
  procurement, 85
Tools:
  cutting tools, 90-91
  extractors, screw and bolt, 98
  miscellaneous tools, 90, 92
  rig pins, 99
  riveting tools, 86-89
  bucking bars, 87-88
  hole finder, 88
  rivet cutters, rotary, 86-87
  riveters, pneumatic:
    corner riveters, 96
    fast hitting, 96
    gun selection, 96-97
    one shot, 96
    slow hitting, 96
    squeeze, 96
  rivet head shaver, 94
  rivet set, 87
  taps and dies, 98
  throw boards, 99-100
  wrenches:
    spanner, 90
    strap, 98
    torque, 90
Torque wrenches, 90-93
Touchup painting, 316-317

Tow bars, 335-337
Towing aircraft, 334-335
Trailer, air/nitrogen, 357-359
Trailing edge repair, 177
Trim tabs, 64-65
Tube assemblies, installation of:
  brazed, 272-274
  flared, 269-270
  flareless, 270-272
  oxygen system, 274
Tube bending:
  hand bender, 264
  mechanical bender, 264

Tube cutting, 263-264
Tube flaring, 264-265, 267
Tubes, inner, 256, 257
Tubing, damaged:
  layout of lines, 263
  removal and replacement, 262-263
Tubing, rigid:
  fittings, 260-262
  sizes, 260
Turnbuckles, 148-149, 221
Turnlock fasteners. (See Fasteners.)
Turrent punch, 102

Unishear, 102
Universal tow bar, 335-337
Vacu-Blast dry honer, 310-314
V-band coupling, 144

Walking beams, 154
Washers, 136, 138
Water emulsion cleaning, 291, 293
Water rinse cleaning, 291
Weight and Balance Data, Manual, 21-22
Wheels, landing, 235-238
  balancing, 238
  demountable flange type, 236
  divided (split) type, 235-236
  maintenance, 238
Wing, rotary, 74-75
Wings, 59-62
Wrought alloys (aluminum), 38

☆ U. S. GOVERNMENT PRINTING OFFICE : 1974 O - 542-195 (17-Z)